Lloyd's Register

Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location, April 2008

Notice No. 3

Effective Date of Latest Amendments:

See page 1

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RULES AND REGULATIONS FOR THE CLASSIFICATION OF A FLOATING OFFSHORE INSTALLATION AT A FIXED LOCATION, *April 2008*

Notice No. 3

This Notice contains amendments within the following Sections of the *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location, April 2008.*
The amendments are effective on the dates shown:

Part	***Chapter***	***Section***	***Effective date***
10	1	Whole Chapter	1 March 2012
10	2	Whole Chapter	1 March 2012
10	3	Whole Chapter	1 March 2012
4	4	Whole Chapter	1 March 2012

It will be noted that the amendments also include corrigenda, which are effective from the date of this Notice.

The *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location, April 2008* are to be read in conjunction with this Notice No. 3. The status of the Rules is now:

Rules for FOIFL	Effective date:	April 2008
Notice No. 1	Effective date:	1 March 2012
Notice No. 2	Effective date:	1 January 2012
Notice No. 3	Effective date:	1 March 2012

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■ *Section 1*
General

1.1 Application

1.1.1 This Chapter outlines the hull structural design requirements of ship units with hull construction in steel engaged in production and/or oil storage/offloading while permanently moored at offshore locations.

1.1.2 The Rules are also applicable to units which normally operate while moored at offshore locations but which are disconnectable in order to avoid extreme environmental conditions or hazards, *see also* Pt 4, Ch 3,4.

1.1.3 Units which operate as shuttle tankers will normally be assigned class in accordance with the *Rules and Regulations for the Classification of Ships*, hereinafter referred to as the Rules for Ships.

1.1.4 Hull strength, scantlings and arrangements for ship units are to comply with Part 10. Reference is also made to the LR *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations* (hereinafter referred to as the *ShipRight* FOI procedure).

1.1.5 All aspects which relate to the specialised offshore function of the unit are to be considered on the basis of this Chapter and the additional requirements related to the design arrangements and functions of drilling and production units given in Pt 3, Ch 2 and 3 are to be complied with.

1.1.6 The scantlings and arrangements of units with a limited number of tanks for the storage of flammable liquids having a flash point not exceeding 60°C (closed-cup test) will be specially considered.

1.1.7 The class notations and descriptive notes applicable to units classed in accordance with these Rules are to be in accordance with Pt 1, Ch 2 and Pt 3, Ch 3,1, to which reference should be made.

1.1.8 Additional requirements related to the design function of the unit are given in Part 3.

1.1.9 Turret structures, mooring arms and yoke structures, etc., are to comply with the requirements of Section 9 and Pt 3, Ch 2.

1.1.10 Units with a process plant facility which comply with the requirements of Pt 3, Ch 8 will be eligible for the assignment of the special features class notation **PPF**.

1.1.11 Units with a drilling plant facility which comply with the requirements of Pt 3, Ch 7 will be eligible for the assignment of the special features class notation **DRILL**.

1.2 Definitions

1.2.1 General definitions are given in Pt 1, Ch 2,2 and Pt 4, Ch 1,5.

1.2.2 Additional definitions relevant to Part 10 are given below:
T_{SC} = deep load draught, in metres, is the maximum draught on which the scantlings are based
T_{LT} = light load draught, in metres, is the minimum draught on which the scantlings are based.

1.2.3 **Moderate service**. A Moderate service is one where the site-specific responses of the vessel are less than or equal to the sea-going responses as a trading ship. The following responses are to be compared:
(a) Hull girder vertical wave bending moment.
(b) Relative wave elevation.
(c) Vertical acceleration.
(d) Roll angle.

1.2.4 **Harsh service**. A Harsh service is one which does not satisfy the definition of a Moderate service.

1.2.5 **Sea-going responses**. The sea-going responses are the responses calculated in accordance with Chapter 2.

■ *Section 2*
Information required

2.1 General

2.1.1 Sufficient plans and supporting data are to be submitted to enable the design of the structure to be assessed. The plans are also to be suitable for use during construction, survey and inspection/maintenance of the unit.

2.1.2 Plans are to be submitted in triplicate, but generally only one copy of supporting design documentation and calculations is required. Plans and supporting documentation should be submitted and approved prior to commencement of construction.

2.1.3 Plans are to contain all necessary information fully to define the structure, including construction details, materials, welding and loads imposed on the structure by equipment and systems, as appropriate.

2.1.4 A copy of the Construction Booklet, Operations Manual and In-Service Inspection Plan must be submitted for class approval, incorporating the final approved revisions of relevant plans and documentation, *see* Pt 1, Ch 3,1.6 and Pt 3, Ch 1.

2.1.5 Plans are to include information related to the renewal thickness as specified in Section 13.

2.1.6 A general list of plans and supporting calculations is given in 2.2. Detailed plan lists can be found in the relevant Sections of the Rules listed below:

Part 3, Chapter 1, Section 5, (Rules for Ships):	Basic Hull structure
Part 1, Chapter 3, Section 1.6:	Planned survey programme
Part 3, Chapter 1, Section 2:	General, OIWS, Construction Booklet
Part 3, Chapter 3, Section 1.6:	Production and oil storage units (general)
Part 3, Chapter 3, Section 2.1:	Production and oil storage units (structure)
Part 3, Chapter 8, Section 1.11:	Process plant facility
Part 3, Chapter 9, Section 1.3:	Dynamic positioning system
Part 3, Chapter 10, Section 1.4:	Positional mooring system
Part 4, Chapter 1, Section 4:	General structure
Part 4, Chapter 6, Section 5.2:	Helideck
Part 4, Chapter 7, Section 1.2:	Watertight/weathertight integrity
Part 8, Chapter 1, Section 3:	Corrosion control.

2.2 Plans and supporting calculations

2.2.1 In general, plans covering the following items are to be submitted:

(a) main scantling plans:
- midship section showing longitudinal and transverse structural members;
- construction profiles/plans showing all main longitudinal structural elements along the unit's length;
- shell expansion;
- main oil-tight and watertight transverse bulkheads including primary support members,

(b) loading guidance information:
- preliminary loading manual;
- final loading manual;
- details of the design basis;
- test conditions for the loading instrument.

(c) detailed construction plans:
- cargo tank construction plans showing the variations in detail arrangements and scantlings of transverse primary support members;
- fore end;
- aft end;
- machinery spaces;
- deck-houses and superstructures;
- bracings and associated primary structure;
- helideck;
- ice strengthening;
- leg structures and spuds;
- materials and grades;
- plans showing the proposed fatigue factors of safety for each part of the structure;

(d) detail design plans, except where the information is already included on plans listed in (a) and (c):
- hull penetration plans;
- welding;
- bilge keels;
- booklet of standard design details;
- pillar and girder support arrangements for decks;
- access arrangements;
- details and arrangements of openings and attachments to the hull structure for means of access for inspection/ maintenance purposes.

(e) plans detailing support structures, except where the information is already included on plans listed in (a) to (d):
- masts, derrick posts, cranes and crane pedestals, flare towers and heavy equipment;
- towing equipment;
- other deck equipment or fittings;
- machinery seatings;
- riser support structures;
- rudder stock, tiller and steering nozzles;
- stern frame and propeller brackets.

(f) The following supporting documents are to be submitted:
- general arrangement;
- capacity plan;
- lines plan or equivalent;
- dry-docking plan, where developed

- freeboard plan or equivalent, showing freeboards and items relative to the conditions of assignment;
- corrosion control scheme;
- towing and anchoring arrangements;
- watertight subdivision;
- welding procedures.

2.3 Plans and information to be supplied on board the unit

2.3.1 One copy of each of the following documents:
(a) main scantling plans, as given in 2.2.1(a);
(b) one copy of the final approved loading manual;
(c) one copy of the final loading instrument test conditions;
(d) detailed construction plans, as given in 2.2.1(c);
(e) welding;
(f) details of the extent and location of higher tensile steel, together with details of the specification and mechanical properties, and any recommendations for welding, working and treatment of these steels;
(g) details and information on use of special materials, such as aluminium alloy, used in the hull construction;
(h) details of the corrosion control system;
(j) operations manual.
Plans are to indicate the new-building and renewal thickness for each structural item.

■ *Section 3*
Materials

3.1 General

3.1.1 Steel should be manufactured and tested in accordance with the Rules for Materials or other acceptable standards. The strength and grades (notch toughness) of steel required will depend on the following:
(a) design temperature;
(b) thickness;
(c) substance being stored/processed;
(d) structural category;
(e) location.

3.1.2 Material classes and steel grades should comply with Pt 4, Ch 2.

3.1.3 Material where the principal loads or welding stresses are perpendicular to the plate thickness should have suitable through-thickness properties. The application of through-thickness property Z25 or Z35 grade material is required where tensile stresses exceed 50 per cent of the Rule permissible stress, with plate thickness in excess of 15 mm. In general, Z25 grade would be required; however, for critical joints, Z35 will be required. For certain critical joints with a restricted load path, these criteria would be subject to special consideration, for example, mooring fairlead attachments and anchor line or hawser connections.

3.1.4 Steel grades for special and primary structural components with thickness in excess of the limitations of Chapter 3 of the Rules for Materials and Table 2.4.1 in Pt 4, Ch 2 will be specially considered.

3.1.5 Where attachments/pads are located on special or primary components which are subjected to high stresses, the attachment is to be of the same material as the plating to which it is attached, with welding to the same standard as the main structure.

3.1.6 Steel having a specified minimum yield stress of 235 N/mm^2 is regarded as normal strength hull structural steel. Steel having a higher specified minimum yield stress is regarded as higher strength hull structural steel.

3.1.7 For the determination of hull girder section modulus, where higher strength hull structural steel is used, a higher strength steel factor, k is given in Table 1.3.1.

Table 1.3.1 Values of *k*

Specified minimum yield stress, N/mm^2	k
235	1,00
265	0,93
315	0,78
340	0,74
355	0,72
390	0,68
NOTE Intermediate values are to be calculated by linear interpolation.	

■ *Section 4*
Structural arrangement

4.1 General

4.1.1 General requirements regarding location and separation of spaces, layout and arrangement of primary structural components are given in Pt 3, Ch 3,1.4. Detailed requirements are given in Ch 1,4.

4.1.2 Overall subdivision of the hull should take full account of strength and stability requirements and minimise the consequences of damage, pollution risk and loss of the unit in the event of damage. Additional subdivision of the hull may be required to account for ballast water needed to control hull stresses and for the storage of process-related liquids.

4.1.3 The Marine Environment Protection Committee of the International Maritime Organization (IMO) has decided that tankers which are used solely for storage and production of oil, and are moored at a fixed location except in extreme environmental or emergency conditions, are not required to comply with all the provisions of the *International Convention for the Prevention of Pollution from Ships, 1973*, as modified by the Protocol of 1978 relating thereto (hereinafter referred to as MARPOL) unless specified in whole or in part by the relevant National Authority. Therefore double hulled construction would not be necessary unless specified by the National Authority.

4.1.4 Account should be taken of the interaction between structural strength and stability. Particular consideration should be given to tank dimensions with respect to tank inspection/maintenance requirements and sloshing/free surface effects for partially filled tanks. Intact and damage stability should comply with applicable National Authority requirements.

4.1.5 Self-propelled floating units should meet the requirements of the *International Convention on Load Lines 1966* (hereinafter referred to as ICLL). Units which do not engage in international voyages, except for transfers between fabrication sites and the installation voyage to the designated site, should have marks which indicate the maximum permissible draught as calculated under the ICLL Requirements.

4.1.6 General requirements for deck layouts/arrangements are given in Pt 3, Ch 3,1.4 and Part 7.

4.1.7 Deck-house superstructures may be located forward or aft of the oil storage tanks. Living quarters, lifeboats and other means of evacuation should be located in non-hazardous areas and be protected and separated from production, storage and turret areas. As a minimum, the arrangement and separation of living quarters, storage tanks, machinery rooms, etc., should be in accordance with the *International Convention for the Safety of Life at Sea, 1974* and its Protocol of 1978 (hereinafter referred to as SOLAS). Where the superstructure is located forward of the cargo tank area, arrangements should provide a suitable level of separation and protection.

4.1.8 The location of the topsides facilities deck and structural arrangements should comply with Pt 3, Ch 3,3.1.4, Pt 3, Ch 3,7 and Ch 3,8 and Part 7 as relevant, together with applicable National Authority codes and standards regarding dangerous zones or divisions and provision of adequate access. Areas and compartments of floating units are defined as hazardous zones according to their proximity to equipment, pipes or tanks containing certain flammable liquids and whether these fluids are at temperatures approaching or exceeding their flashpoints, *see* Pt 7, Ch 2.

4.1.9 Alternative arrangements which are proposed as being equivalent to the Rules will receive individual consideration, taking into account any relevant National Authority requirements.

4.1.10 Reference should also be made to SOLAS and applicable amendments.

4.1.11 The number of openings in watertight bulkheads is to be kept to a minimum. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

4.2 Arrangement for turrets

4.2.1 A cofferdam or equivalent is to be arranged between bulk oil storage tanks and the turret casing or turret equipment spaces internal to the hull. The scantlings and testing requirements are to comply with Rule requirements for cofferdam bulkheads. Suitable corrosion protection, drainage and gas freeing arrangements are to be provided to such spaces. A pump room, void space or water ballast tank will be accepted in lieu of a cofferdam.

4.2.2 The bulkheads bounding the turret space are to comply with the scantling requirements for side shell structure and for bulkheads. Blast loading is also to be considered.

4.3 Structural continuity

4.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

4.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

■ *Section 5*

Structural design – New-build units

5.1 General

5.1.1 This Section outlines the hull structural calculation and analysis requirements for new-build ship units engaged in production and/or oil storage/offloading moored at offshore locations. Requirements are given for permanently moored units and disconnectable units.

5.1.2 The hull structure is to be designed to withstand the static and dynamic loads imposed on the structure in all operating conditions and all anticipated pre-service conditions. All relevant loads as defined in Chapter 3 are to be considered, including the effects of partial and/or non-homogeneous loading in oil bulk storage tanks. When considering the design loading conditions, the Owner/designer is to take account of the requirements for on-station tank inspection/maintenance. Loads during construction, installation and decommissioning, towing/transportation should be considered, as applicable. Reference is also made to the *ShipRight-FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

5.1.3 The assessment of environmental loads may be based on the results of model tests and/or by suitable direct calculation methods of the actual loads on the hull at the site-specific location, taking into account the following service-related factors:
(a) site-specific environmental loads including relevant non-linear effects;
(b) mooring system and riser loads;
(c) unit orientation and wave loading directions;
(d) long-term service effects at a fixed location;
(e) range of tank loading conditions, including empty tanks required for on-station surveys;
(f) potential relocations if applicable.

5.1.4 For Moderate service the site-specific loads can be used. The sea-going loads for world-wide service from Chapter 2 may be used at the Owner's discretion. For Harsh service the site-specific loads must be used. Where the unit is intended for operation at more than one location, the most severe design criteria are to be applied. Where the **ShipRight–FOI RBA(S)** notation is assigned then the site-specific loads must be used.

5.1.5 On-site tank inspections/maintenance are to be restricted to reasonable weather as defined in Pt 1, Ch 2. For design purposes, the permissible still water bending moments and shear forces for tank inspection/maintenance conditions may be based on 100-year return period seasonal site criteria. Tank inspection/maintenance conditions are to be included in the unit's loading manual and the limiting environmental criteria are to be defined in the Operations Manual.

5.1.6 Where it is intended to dry-dock a unit during its service life, this is to be taken into account at the design stage and the docking condition is to be submitted to LR for approval. The bottom structure should be suitably strengthened to withstand the bearing pressures and loads imposed by dry-docking.

5.1.7 Disconnectable units, as defined in 1.1.2, will remain in class in the sail-away condition and the loading conditions are to be submitted for approval.

5.1.8 The hull structure of disconnectable units (when disconnected) is to be assessed for unrestricted service as a sea-going oil tanker. *See* Ch 2,3.3.

5.1.9 The general requirements for investigating accidental loads are defined in Pt 4, Ch 3,4.16. Collision loads against the hull structure will normally only cause local damage to the hull structure and consequently need not be investigated from the overall strength aspects.

5.1.10 Structural strength and fatigue analyses are generally required to verify that hull structure and critical structural connections, when subjected to the site-specific load combinations and other relevant load combinations, are suitable for the required service life on location.

5.1.11 Hull integration structure in way of moorings, topsides and other concentrated loads is to be verified by direct calculations. Permissible stress levels are to be in accordance with Chapter 3 or Pt 4, Ch 6, corrected as necessary for the effect of variation in static loads as given in Section 5 of the *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

5.1.12 Where permitted by the relevant National Authority, single hulled units may be accepted.

5.1.13 Sufficiently robust underdeck reinforcement should be provided in the way of the welded connections of the topsides support structure to the main hull. The support structures should be aligned with the primary members of the hull structure.

5.1.14 Hull structure and mooring integration structures: for disconnectable units at locations exposed to cyclones, the environmental loads when disconnected are not to be taken less than required by Chapter 2 for world-wide service.

5.2 Hull scantlings

5.2.1 The longitudinal strength of the unit is to comply with the requirements of Chapter 3. The total stresses from the combined effects of site-specific wave loads, still water loads, mooring loads, etc., are not to exceed permissible values.

5.2.2 When the site-specific wave bending moments and shear forces are below the values for unrestricted sea-going service, the site-specific values may generally be used for design, *see* 5.1.4. However, in no case are the site-specific wave bending moments and shear forces to be taken as less than 50 per cent of the value for unrestricted sea-going service.

5.2.3 The requirement for hull girder inertia given in Chapter 3 is to be complied with.

5.2.4 The strength of the unit in the transit condition and in the site-specific installation condition is to be investigated and submitted to LR for approval.

5.2.5 For initial design purposes, site-specific Environmental FOI factors (EFF) are given in Ch 2,3.3 with the associated Dynamic Load Combination factors (DLCF) given in Ch 2,7 for the Transit/Disconnected condition and Ch 2,8 for the On-site Operational condition. Where EFFs and DLCFs for a particular field are not given in the Rules, they may be estimated using LR's EFM estimation tool.

5.2.6 For the final design, the loads derived in accordance with the ShipRight FOI procedure must be used.

5.3 Strength analysis

5.3.1 The scantlings of primary structure of the oil bulk storage tank area are to be verified by direct calculations based on a three-dimensional finite plate element analysis carried out in accordance with the LR *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

5.3.2 The corrosion additions are to be determined as described in Section 12.

5.4 Fatigue analysis

5.4.1 The fatigue assessment of the hull structure of ship units is to be verified in accordance with the LR *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

5.4.2 In all cases, the fatigue assessment should address the primary hull structure connections, primary topside support structure and hull integration, together with other primary structure connections subject to significant dynamic loading. Account should be taken of all important sources of cyclic loading, *see also* Pt 4, Ch 6,5.2.

5.4.3 Fatigue calculations for the mooring structures and integration of the mooring system within the unit's hull structure are also to be carried out, *see* Pt 3, Ch 10.

5.4.4 The turret-bearing support structures are to be assessed for fatigue damage due to cyclic loading in accordance with Pt 4, Ch 6,5.

5.4.5 The general requirements for fatigue design and factors of safety on fatigue life for supporting structures to drilling and process plant, flare towers, derricks, cranes and crane pedestals and mooring structures are to comply with Pt 4, Ch 6,5.

5.4.6 The minimum design fatigue life for structural elements should not be less than the intended field life, but in general should not be less than 25 years. The cumulative damage ratio for individual components should take account of the degree of redundancy and accessibility of the structure and also the consequence of failure, *see also* Pt 4, Ch 6,5.

■ *Section 6*

Structural design – Tanker conversions

6.1 General

6.1.1 This Section outlines the hull structural calculations and analysis requirements for tanker conversions engaged in production and/or oil storage/offloading moored at offshore locations. Requirements are given for permanently moored units and disconnectable units. At the Owner's request, the requirements given in Section 5 may be applied instead of the requirements given in this Section.

6.1.2 The hull structure is to be designed to withstand the static and dynamic loads imposed on the structure in all operating conditions and all anticipated pre-service conditions. All relevant loads as defined in Pt 4, Ch 3 are to be considered and the effects of partial and/or non-homogeneous loading in oil bulk storage tanks are to be considered. When considering the design loading conditions, the Owner/designer is to take account of the requirements for on-station tank inspection/maintenance. Loads during construction, installation and decommissioning, towing/transportation should be considered, as applicable. Reference is also made to the *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

6.1.3 The assessment of environmental loads may be based on the results of model tests and/or by suitable direct calculation methods of the actual loads on the hull at the site-specific location, taking into account the following service-related factors:
(a) Site-specific environmental loads including relevant non-linear effects.
(b) Mooring system and riser loads.
(c) Unit orientation and wave loading directions.
(d) Long-term service effects at a fixed location.
(e) Range of tank loading conditions, including empty tanks required for on-station surveys.
(f) Potential relocations if applicable.

6.1.4 For Moderate service the site-specific loads can be used. The sea-going loads for world-wide service from Chapter 2 may be used at the Owner's discretion. For Harsh service the unit is to be reassessed as for a new build. Where the unit is intended for operation at more than one location, the most severe design criteria are to be applied.

6.1.5 Where a unit is intended to operate in Moderate Environments, the existing scantlings of the hull need not be re-assessed, subject to the following conditions:

- the vessel was built under the survey of a member of IACS before conversion;
- the vessel has been maintained in Class by a member of IACS before conversion;
- CAP assessment 1 or 2 assigned;
- all necessary repairs are made to delete any Conditions of Class;
- the in-service corrosion margins applied after conversion are the same as those applicable as a trading tanker;
- LR Transfer of Class (TOC) procedures are complied with if the vessel is transferring Class to LR;

- a Special Survey is conducted during the conversion;
- the loading on the structure is not increased;
- the structure is not changed;
- the vessel was originally approved for world-wide service.

Where these conditions are not met (for example, turret integration structure, supporting structure under topsides and crane pedestals) then the structure is to be re-assessed in accordance with Section 5.

6.1.6 For Moderate service further to the reassessment criteria specified in 6.1.5, the hull scantlings are to be reassessed where the **ShipRight–FOI RBA(S)** notation is assigned. If the structure is modified or the loading changed then the hull scantlings affected by these changes should be reassessed. Hull scantlings of a conversion may need to be reassessed for the following reasons:

- integration of the mooring system of an internal turret;
- loads from topsides equipment on the upper deck;
- redefinition of loading limitations assigned as a tanker (for example, changes to permissible still water bending moments and shear forces) where required for unit-specific loading conditions;
- measured corrosion found to be in excess of that permitted for a trading tanker; and
- the low variability of the operating loads results in factor of safety F_{FOI} of more than 1,0 for the hull girder shear and bending stresses (*see* Table 5-2 of the *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*).

6.1.7 On-site tank inspections/maintenance are to be restricted to reasonable weather as defined in Pt 1, Ch 2. For design purposes, the permissible still water wave bending moments and shear forces for tank inspection/maintenance conditions may be based on the existing assigned permissible still water values. Where the existing assigned permissible still water values are insufficient, wave bending moments and shear forces may be based on 100-year return period seasonal site criteria and still water permissible values adjusted accordingly. Tank inspection/maintenance conditions are to be included in the unit's loading manual and the limiting environmental criteria are to be defined in the Operations Manual.

6.1.8 Where it is intended to dry-dock a unit during its service life, this is to be taken into account at the design stage and the docking condition is to be submitted to LR for approval. The bottom structure should be suitably strengthened to withstand the bearing pressures and loads imposed by dry-docking.

6.1.9 Disconnectable units, as defined in 1.1.2, will remain in class in the sail-away condition and the loading conditions are to be submitted for approval.

6.1.10 The hull structure of disconnectable units (when disconnected) is to be assessed for unrestricted service as a sea-going oil tanker.

6.1.11 The general requirements for investigating accidental loads are defined in Pt 4, Ch 3,4.16. Collision loads against the hull structure will normally only cause local damage to the hull structure and consequently need not be investigated from the overall strength aspects.

6.1.12 Structural strength and fatigue analyses are generally required to verify that hull structure and critical structural connections, when subjected to the site-specific load combinations and other relevant load combinations, are suitable for the required service life on location.

6.1.13 Hull integration structure in way of moorings, topsides, crane pedestals, flare towers and other concentrated loads is to be verified by direct calculations. Permissible stress levels are to be in accordance with Pt 4, Ch 6 or Chapter 2, corrected as necessary for the effect of variation in static loads as given in Section 5 of the *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

6.1.14 The detailed scope of analysis required for hull structural assessments of tanker conversions will be considered on a case-by-case basis, *see* 6.2.

6.1.15 Where permitted by the relevant National Authority, single hulled units may be accepted.

6.1.16 Sufficiently robust underdeck reinforcement should be provided in way of the welded connections of the topsides support structure to the main hull. Special attention should be given to alignment of primary members.

6.1.17 Mooring and hull integration structures of disconnectable units (when disconnected) are to take into account the 100-year site-specific cyclonic loading. Loading combinations are to be developed in a rational manner.

6.1.18 For units permanently moored by the stern, the structural arrangements and scantlings of all exposed structure located in the aft end of the unit are to be specially considered. The strengthening of the bottom structure is to be specially considered.

6.2 Hull scantlings

6.2.1 Hull scantlings are to be re-assessed in accordance with the requirements for new build units, *see* 5.3, whenever any of the following apply:

(a) The unit is to be deployed in harsh service;
(b) The total hull girder bending moments (hogging and sagging) approved prior to conversion, i.e. vertical wave bending moment + permissible still water vertical bending moment, are exceeded; or
(c) The total hull girder shear forces (positive and negative) approved prior to conversion, i.e. vertical wave shear force + permissible still water vertical shear force, are exceeded.

6.2.2 When the site-specific wave bending moments and shear forces are below the values for unrestricted sea-going service, the site-specific values may generally be used for design, *see* 6.1.4. However, in no case are the site-specific wave bending moments and shear forces to be taken as less than 50 per cent of the value for unrestricted sea-going service.

6.2.3 If the environmental FOI factors, as defined in Ch 2,3.1, calculated for the hull girder bending moments ($f_{\text{FOI-Mwv}}$ or $f_{\text{FOI-Mwv-h}}$) or shear force ($f_{\text{FOI-Qwv}}$) exceed 1,0, then the hull scantlings are to be re-assessed in accordance with the requirements for new build units, *see* 5.3.

6.2.4 The strength of the unit in the transit condition and in the site-specific installation condition is to be investigated and submitted to LR for approval.

6.2.5 Where the conversion includes provision for an internal turret mooring system, the effects of such openings and reinforcement structure on hull girder strength should be evaluated.

6.2.6 It is recommended that, in general, corrosion additions are to be determined based on Section 12; however, consideration will be given to alternative proposals submitted by the Owner.

6.3 Fatigue analysis

6.3.1 The fatigue assessment of the hull structure of ship units is to be verified in accordance with LR's *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

6.3.2 In all cases, the fatigue assessment should address the primary hull structure connections, primary topside support structure and hull integration, together with other primary structure connections subject to significant dynamic loading. Account should be taken of all important sources of cyclic loading. *See also* Pt 4, Ch 6,5.2.

6.3.3 Fatigue calculations for the mooring structure and integration of the mooring system within the unit's hull structure are also to be carried out, *see* Pt 3, Ch 10.

6.3.4 The turret-bearing support structures are to be assessed for fatigue damage due to cyclic loading, in accordance with Pt 4, Ch 6,5.

6.3.5 The general requirements for fatigue design and factors of safety on fatigue life for supporting structures to drilling and process plant, flare towers, derricks, cranes and crane pedestals and mooring structures are to comply with Pt 4, Ch 6,5.

6.3.6 Fatigue calculations for installations based on tanker conversions should take into account the fatigue damage accumulated as a trading tanker prior to conversion. The design corrosion additions are to be deducted from the scantlings measured at the time of conversion, as described in LR's *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*. This is to ensure the calculation of fatigue damage after conversion accounts for any reduction in the as-built scantlings. The analysis is required to verify that the remaining fatigue life of the converted hull structure is compatible with the required service life on location, *see also* 6.3.7.

6.3.7 The minimum design fatigue life (after accounting for fatigue damage accumulated as a trading tanker prior to conversion) for structural elements should not be less than the intended field life, but should not be less than 5 years. The cumulative damage ratio for individual components should take account of the degree of redundancy and accessibility of the structure and also the consequence of failure, *see also* Pt 4, Ch 6,5.

6.3.8 The in-service Class survey reports for the vessel from build until conversion are to be submitted to LR for review. All critical locations in the existing structure which may be prone to fatigue cracking are to be examined by MPI or other suitable NDE methods at the time of conversion. The critical locations are to be selected based on the previous service history of the vessel and the recommendations in the LR ShipRight–*FOI Design, Construction and Operation Procedure for Floating Offshore Installations*. A detailed NDE plan is to be submitted for approval.

■ *Section 7*
Redeployment of existing units

7.1 General

7.1.1 If the 100-year environmental loads are larger than those of the previous geographical location then the requirements of Section 6 are to be applied for the redeployment of existing ship units.

7.2 Fatigue analysis

7.2.1 Fatigue calculations should take into account the fatigue damage accumulated prior to redeployment. The design corrosion additions are to be deducted from the scantlings measured at the time of redeployment, as described in LR's *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*. This is to ensure the calculation of fatigue damage after redeployment accounts for any reduction in the as-built scantlings. The analysis is required to verify that the remaining fatigue life of the hull structure is compatible with the required service life on location, *see also* 6.3.7.

■ *Section 8*
Structural idealisation

8.1 General

8.1.1 General structural idealisation is covered in Pt 4, Ch 3,3. Additional approaches relevant to Part 10 are given in this Section.

8.2 Mixed steel grades

8.2.1 When a stiffener is of a higher strength material than the attached plate, the yield stress used for the calculation of the section modulus requirements in Chapter 3 is, in general, not to be greater than 1,35 times the minimum specified yield stress of the attached plate. If the yield stress of the stiffener exceeds this limitation, the following criterion is to be satisfied:

$$\sigma_{yd\text{-}stf} \leq (\sigma_{yd\text{-}plt} - |\,\sigma_{hg}\,|\,)\,\frac{Z_{net\text{-}plt}}{Z_{net}} + |\,\sigma_{hg}\,| \quad \text{N/mm}^2$$

where

$\sigma_{yd\text{-}stf}$ = specified minimum yield stress of the material of the stiffener, in N/mm^2

$\sigma_{yd\text{-}plt}$ = specified minimum yield stress of the material of the attached plate, in N/mm^2

σ_{hg} = maximum hull girder stress of sagging and hogging, in N/mm^2, as defined in Table 3.2.5 and Table 3.4.3 in Chapter 3, for stiffeners in cargo tank region and machinery spaces respectively and not to be taken as less than $0{,}4\sigma_{yd\text{-}plt}$

Z_{net} = net section modulus, in way of face plate/free edge of the stiffener, in cm^3

$Z_{net\text{-}plt}$ = net section modulus, in way of the attached plate of stiffener, in cm^3.

8.3 Effective shear span

8.3.1 The effective shear span of a stiffener may be reduced due to the presence of brackets, provided the brackets are effectively supported by the adjacent structure, otherwise the effective shear span is to be as the full length, as given in 8.3.3.

8.3.2 The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener. If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to that of the stiffener, the effective shear span may be calculated using the longer effective bracket arm.

8.3.3 The effective shear span may be reduced by a minimum of s/4000 m at each end of the member, regardless of support detail, hence the effective shear span is not to be taken greater than:

$$l_{shr} \leq l - \frac{s}{2000} \quad \text{m}$$

where

l = full length of the stiffener between primary support members, in metres
s = stiffener spacing, in mm.

8.4 Effective elastic sectional properties of local support members

8.4.1 The net elastic shear area of local support members is to be taken as:

$$A_{shr-el-net} = \frac{(h_{stf} + t_{p-net})\, t_{w-net} \sin \varphi_w}{100} \quad \text{cm}^2$$

where
h_{stf} = stiffener height, including face plate, in mm
$t_{p\text{-}net}$ = net thickness of attached plate, in mm
$t_{w\text{-}net}$ = net web thickness, in mm
φ_w = angle between the stiffener web and attached plating, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75°.

8.4.2 The effective shear depth of stiffeners is to be taken as:

$$d_{shr} = (h_{stf} + t_{p-net}) \sin \varphi_w \quad \text{mm}$$

where
h_{stf}, $t_{p\text{-}net}$, φ_w are defined in 8.4.1.

8.4.3 The elastic net section modulus of local support members is to be taken as:

$$Z_{el-\varphi-net} = Z_{stf-net} \sin\varphi_w \quad \text{cm}^3$$

where
$Z_{stf\text{-}net}$ = net section modulus of corresponding upright stiffener, i.e. when φ_w is equal to 90°, in cm^3
φ_w is defined in 8.4.1.

8.5 Effective plastic section modulus and shear area of stiffeners

8.5.1 The net plastic shear area of local support members is to be taken as:

$$A_{shr-pl-net} = \frac{(h_{stf} + t_{p-net})\, t_{w-net} \sin \varphi_w}{100} \quad \text{cm}^2$$

where
h_{stf}, $t_{p\text{-}net}$, φ_w are defined in 8.4.1
$t_{w\text{-}net}$ = net web thickness, in mm.

8.5.2 The effective net plastic section modulus of local support members is to be taken as:

$$Z_{pl-net} = \frac{f_w\, d_w^2\, t_{w-net} \sin\varphi_w}{2000} + \frac{(2\gamma - 1)\, A_{f-net}\, (h_{f-ctr} \sin\varphi_w - b_{f-ctr} \cos\varphi_w)}{1000} \quad \text{cm}^3$$

where
f_w = web shear stress factor
= 0,75 for flanged profile cross-sections with n = 1 or 2
= 1,0 for flanged profile cross-sections with n = 0 and for flat bar stiffeners
n = number of moment effective end supports of each member
= 0, 1 or 2

A moment effective end support may be considered where:

(a) the stiffener is continuous at the support;
(b) the stiffener passes through the support plate while it is connected at its termination point by a carling (or equivalent) to adjacent stiffeners;
(c) the stiffener is attached to an abutting stiffener effective in bending (not a buckling stiffener) or bracket. The bracket is assumed to be bending effective when it is attached to another stiffener (not a buckling stiffener).

d_w = depth of stiffener web, in mm:
= $h_{stf\text{-}tf\text{-}net}$ for T, L (rolled and built up) and L2 profiles
= h_{stf} for flat bar and L3 profiles to be taken as given in Table 1.8.1 and Table 1.8.2 for bulb profiles
γ = $0{,}25\,(1 + \sqrt{3 + 12\beta})$
β = 0,5 for all cases, except L profiles without a mid span tripping bracket

$$= \frac{10^6\, t_{w\text{-}net}^2\, f_b\, l_f^2}{80 b_f^2\, t_{f\text{-}net}\, h_{f\text{-}ctr}} + \frac{t_{w\text{-}net}}{2b_f}$$

but not to be taken greater than 0,5 for L (rolled and built-up) profiles without a mid span tripping bracket

$A_{f\text{-}net}$ = net cross-sectional area of flange, in mm^2:
= $b_f\, t_{f\text{-}net}$ in general
= 0 for flat bar stiffeners
b_f = breadth of flange, in mm. For bulb profiles, *see* Table 1.8.1 and Table 1.8.2
$b_{f\text{-}ctr}$ = distance from mid thickness of stiffener web to the centre of the flange area:
= 0,5 ($b_f - t_{w\text{-}grs}$) for rolled angle profiles
= 0 for T profiles
as given in Table 1.8.1 and Table 1.8.2 for bulb profiles
$h_{f\text{-}ctr}$ = height of stiffener measured to the mid thickness of the flange:
= $h_{stf} - 0{,}5 t_{f\text{-}net}$ for profiles with flange of rectangular shape except for L3 profiles
= $h_{stf} - d_{edge} - 0{,}5\, t_{f\text{-}net}$ for L3 profiles
as given in Table 1.8.1 and Table 1.8.2 for bulb profiles
d_{edge} distance from upper edge of web to the top of the flange, in mm
f_b = 1,0 in general
= 0,8 for continuous flanges with end bracket(s). A continuous flange is defined as a flange that is not sniped and continuous through the primary support member
= 0,7 for non-continuous flanges with end bracket(s). A non-continuous flange is defined as a flange that is sniped at the primary support member or terminated at the support without aligned structure on the other side of the support
l_f = length of stiffener flange between supporting webs, in metres, but reduced by the arm length of end bracket(s) for stiffeners with end bracket(s) fitted
$t_{f\text{-}net}$ = net flange thickness, in mm
= 0 for flat bar stiffeners
as given in Table 1.8.1 and Table 1.8.2 for bulb profiles
$t_{w\text{-}net}$, h_{stf}, φ_w are defined in 8.4.1.

Table 1.8.1 Characteristic flange data for HP bulb profiles (*see* Fig. 1.8.1)

h_{stf} (mm)	d_w (mm)	$b_{f\text{-}grs}^*$ (mm)	$t_{f\text{-}grs}^*$ (mm)	$b_{f\text{-}ctr}$ (mm)	$h_{f\text{-}ctr}$ (mm)
200	171	40	14,4	10,9	188
220	188	44	16,2	12,1	206
240	205	49	17,7	13,3	225
260	221	53	19,5	14,5	244
280	238	57	21,3	15,8	263
300	255	62	22,8	16,9	281
320	271	65	25,0	18,1	300
340	288	70	26,4	19,3	318
370	313	77	28,8	21,1	346
400	338	83	31,5	22,0	374
430	363	90	33,9	24,7	402

NOTE
Characteristic flange data converted to net scantlings are given as:
b_f = $b_{f\text{-}grs}^* + 2t_{w\text{-}net}$
$t_{f\text{-}net}$ = $t_{f\text{-}grs}^* - t_{corr}$
$t_{w\text{-}net}$ = $t_{wgrs} - t_{corr}$

Table 1.8.2 **Characteristic flange data for JIS bulb profiles** (*see* Fig. 1.8.1)

h_{stf} (mm)	d_w (mm)	$b_{f\text{-}grs}$* (mm)	$t_{f\text{-}grs}$* (mm)	$b_{f\text{-}ctr}$ (mm)	$h_{f\text{-}ctr}$ (mm)
180	156	34	11,9	9,0	170
200	172	39	13,7	10,4	188
230	198	45	15,2	11,7	217
250	215	49	17,1	12,9	235
NOTE Characteristic flange data converted to net scantlings are as given in Table 1.8.1.					

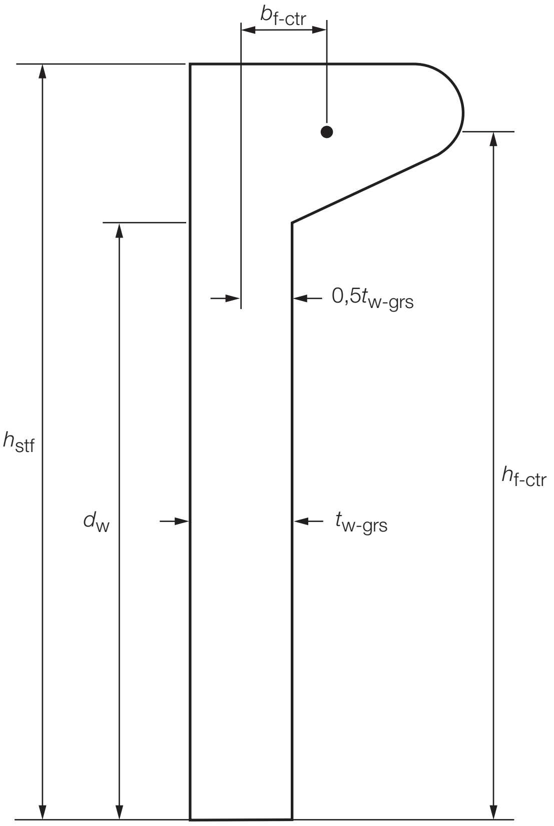


Fig. 1.8.1 **Characteristic data for bulb profiles**

■ *Section 9*
Mooring structure

9.1 General

9.1.1 General requirements for turret mooring structures are given in Pt 3, Ch 2,3.

9.1.2 General requirements for mooring arm structures are given in Pt 3, Ch 2,4.

9.1.3 The minimum hull modulus in way of turret areas and other large openings is to satisfy the Rule requirements for longitudinal strength. When the turret is situated within 0,5*L* amidships, the minimum hull midship section modulus about the transverse neutral axis at deck or keel is to be maintained in way of the turret opening. Increases in plate thicknesses are to take place gradually. Any reduction in hull section modulus should be kept to a minimum and compensation fitted where necessary.

9.1.4 For a turret-moored unit with a turret well opening, suitable precautions are to be taken to prevent damage to the well structure in transit and when disconnected, when applicable.

9.1.5 The hull structure in way of mooring connections is to be verified by direct calculation. In all cases, the structural analysis is to include a representative portion of the hull and tank structure together with the integration of the mooring system with the unit's structure. The analysis is to be in accordance with the LR *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations* and Pt 4, Ch 6, as applicable.

9.1.6 Continuity of primary structural elements is to be maintained as far as practicable in way of turret openings and mooring support structure.

9.1.7 Turret bearings are to comply with Pt 3, Ch 2. The turret bearing support structure is to be integrated into the hull structure.

■ *Section 10*
Topside structure

10.1 General

10.1.1 The minimum scantlings of superstructures and deck-houses are to comply with the requirements of Pt 3, Ch 8 of the Rules for Ships. Bulwarks and guard-rails are to comply with Pt 4, Ch 7,10 but special consideration is to be given to the scantlings of bulwarks at the fore end or screens protecting the swivel stack. In general, the scantlings of bulwarks at the fore end are not to be less than required for deck-house fronts at the position under consideration.

10.1.2 For units with unconventional forward ends and units which may be subjected to high deck loading in excess of the minimum Rule heads due to loading from green seas, adequate protection by means of bulwarks and breakwater structure are to be provided at the forward end and the scantlings of the structure and its under-deck supports are to be specially considered. Where necessary the loadings are to be determined by model tests.

10.1.3 The boundary bulkheads of accommodation spaces which may be subjected to blast loading in accordance with Pt 7, Ch 3 are to be designed in accordance with Pt 4, Ch 3,4 and permissible stress levels are to satisfy the factors of safety given in Pt 4, Ch 6,2.1.1(c).

10.1.4 For units fitted with a process plant facility and/or drilling equipment, the support stools and integrated hull support structure to the process plant and other equipment-supporting structures, including derricks and flare structures, are considered to be classification items, regardless of whether or not the process/drilling plant facility is classed, and the loadings are to be determined in accordance with Pt 3, Ch 8,2. Loading from the topsides should consider the most onerous scenarios, including environmental loads, equipment operating weights and inertia loads due to hull motions. Permissible stress levels are to comply with Pt 4, Ch 6 or Chapter 3, corrected as necessary for the effect of variation in static loads as given in Section 5 of the *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

10.1.5 Equipment supports are to take into account hull deflections when considered necessary.

■ *Section 11*
Green water and wave impact

11.1 General

11.1.1 Green water is taken to mean the overtopping by water in severe wave conditions, resulting in loading on the deck structure and any exposed equipment. Significant amounts of green water will have an impact on the vessel deck structural design, accommodation superstructure, equipment design and layout and may induce vibrations in the hull. The effects of green water loading should be accounted for, where applicable.

11.1.2 The requirements of, Ch 2,3.8, Ch 2,7.4 and Ch 3,6 are to be complied with, *see also* Section 5 and Section 6.

11.1.3 Appropriate measures should be considered to minimise green water effects on the structure and critical equipment, including bow shape design, flare, breakwaters and other protective structure such as turret housings. Adequate drainage arrangements must also be provided, *see also* Pt 4, Ch 7,10.

11.1.4 Wave slamming effects should be taken into account for both hull and mooring structure design. Locations on the hull which may be subject to effects of wave impact include the forward bottom structure, stern structure, bow flare and bow side. The effects of slamming on the structure should be considered in design, particularly with regard to enhancement of global hull girder bending moments and shear loadings induced, local strength aspects and limitations to ballast draft conditions.

11.1.5 It is recommended that provisions are made during model testing for measurement of both green water loading and wave slamming pressures which can be used for local structural design.

■ *Section 12*
Corrosion additions

12.1 General

12.1.1 The net scantling approach is described in 12.2. Corrosion additions are defined in 12.3 and in-operation steel renewal criteria are defined in Section 13.

12.1.2 The requirements for corrosion protection given in Part 8 are to be complied with.

12.2 Net scantling approach

12.2.1 The net thickness of a structural element is that required for structural strength compliance with the design basis. The corrosion addition for structural elements is derived independently of the net scantling requirements. This approach clearly separates the net thickness from the thickness added to address the corrosion that is likely to occur during the in-operation phase. This approach enables the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the unit. *See* Fig. 1.12.1.

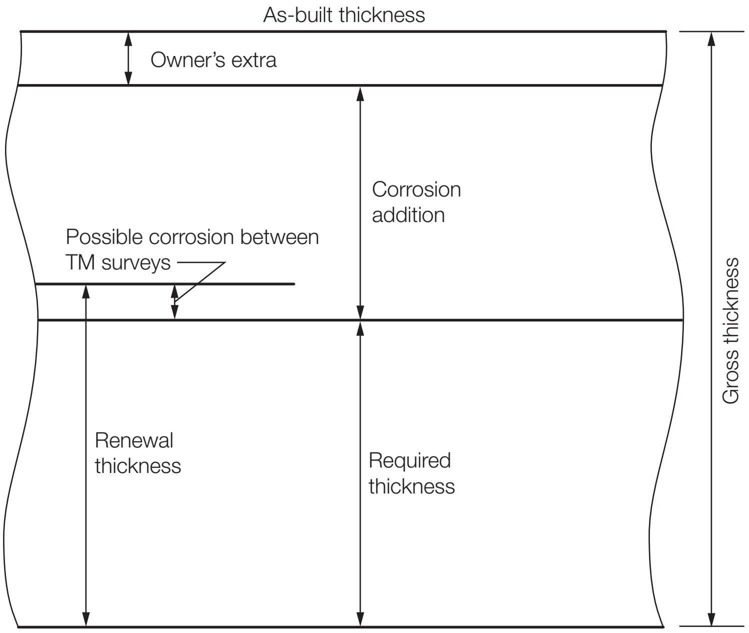
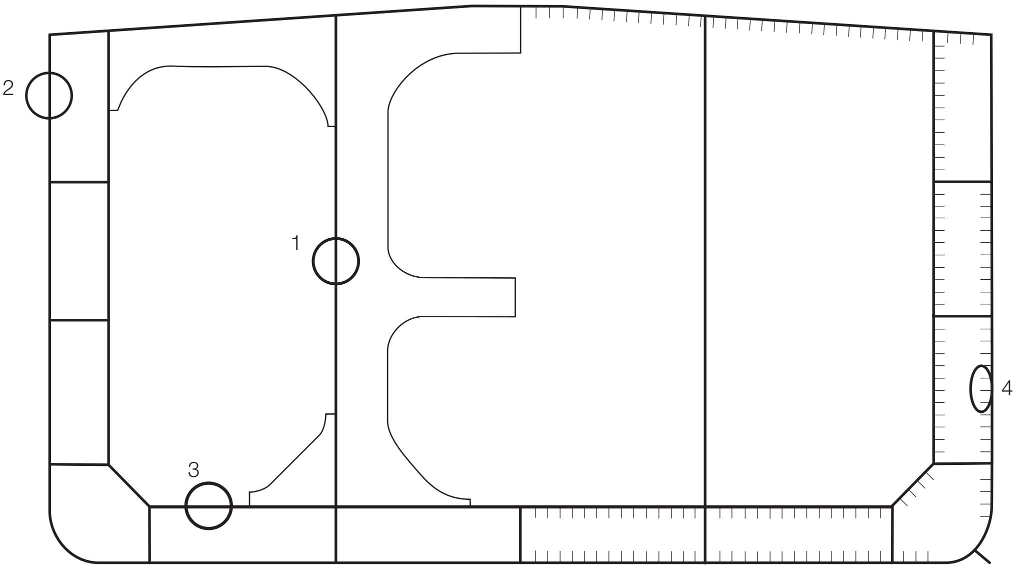


Fig. 1.12.1 Net scantling approach



1 **Longitudinal bulkhead plating**
Corrosion addition (Table 1.12.1) = 0,075 mm/year for each side of the plating
Unit design life = 25 years
Effective coating life = 15 years
Total corrosion addition = (25 – 15) x (0,075 + 0,075) = 10 x 0,15 = 1,5 mm

2 **Side shell plating (within 3 m below top of tank)**
Corrosion addition (Table 1.12.1) = 0,075 mm/year for side shell plating
Corrosion addition (Table 1.12.1) = 0,15 mm/year for ballast water tank
Unit design life = 25 years
Effective coating life = 15 years
Total corrosion addition = (25 – 15) x (0,075 + 0,15) = 10 x 0,225 = 2,25 mm = 2,5 mm rounded

3 **Cargo tank bottom plating**
Corrosion addition (Table 1.12.1) = 0,075 mm/year for cargo tank plating
Corrosion addition (Table 1.12.1) = 0,1 mm/year for ballast water tank
Unit design life = 25 years
Effective coating life = 15 years
Total corrosion addition = (25 – 15) x (0,075 + 0,1) = 10 x 0,175 = 1,75 mm = 2 mm rounded

4 **Stiffeners in ballast water tank**
Corrosion addition (Table 1.12.1) = 0,1 mm/year for each side in ballast water tank
Unit design life = 25 years
Effective coating life = 15 years
Total corrosion addition = (25 – 15) x (0,1 + 0,1) = 10 x 0,2 = 2 mm

NOTE
This example assumes that the tanks will spend 50 per cent of the time empty and 50 per cent of the time full over the unit design life.

Fig. 1.12.2 Example calculations of corrosion additions

12.2.2 The net thickness approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the overall average corrosion of larger areas such as primary support members and the hull girder.

12.3 Corrosion additions

12.3.1 The corrosion additions specified in this sub-Section are applicable to each of the two sides of a structural member and are given as a corrosion rate. The corrosion rate for each of the two sides of a structural member is specified in Table 1.12.1.

Table 1.12.1 Corrosion rate for one side of structural member

Compartment type	Structural member	Corrosion rate t_{c1}, t_{c2} (mm/year)
Ballast water tank	Within 3 m below top tank (*see* Note 1) Elsewhere	0,15 0,1
Cargo oil tank	Within 3 m below top of tank (*see* Note 1) Bottom of single bottom tanks Elsewhere	0,125 0,125 0,075
Exposed to atmosphere	Weather deck plating Other members	0,1 0,075
Exposed to sea-water	Shell plating	0,075
Fuel and lubricating oil tank (*see* Note 3)		0,05
Fresh water tank		0,05
Slop tanks		0,15
Void spaces (*see* Note 2)	Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, inner surface of stool space common with a dry bulk cargo hold, etc.	0,05
Dry spaces	Internals of machinery spaces, pump room, store rooms, steering gear space, etc.	0,05

NOTES

1. This is only applicable to cargo tanks and ballast tanks with weather deck as the tank top.
2. The corrosion rate on the outer shell plating in way of a pipe tunnel is to be taken as for a water ballast tank.
3. 0,07 mm/year is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated cargo oil tanks. 0,03 mm/year is to be added to each surface of the web and face plate of a stiffener in a ballast tank and attached to the boundary between water ballast and heated cargo oil tanks. Heated cargo oil tanks are defined as tanks arranged with any form of heating capability.

12.3.2 The total corrosion addition for a structural member is given by the following formula:

$t_c = N_c (t_{c1} + t_{c2})$ mm, rounded up to the nearest 0,5 mm

where

N_c = number of years of unit life where coating is not fully effective, *see* Fig. 1.12.3. N_c is not to be less than 10 years for new-builds and not less than 5 years for conversions and redeployments. Where cargo tanks remain uncoated, N_c is to be taken as equal to the unit design life

t_{c1}, t_{c2} = corrosion rate for each side of the structural member, as given in Table 1.12.1

For example calculations of corrosion additions, *see* Fig. 1.12.2.

12.3.3 The corrosion rates for cargo and ballast water tanks given in Table 1.12.1 assume the tanks will spend 50 per cent of the time empty and 50 per cent of the time full over the unit design life and that the ballast tank is fitted with effective anodes. Where alternative regimes for individual tanks are specified, the corrosion rate may be adjusted by [percentage time empty/50] x corrosion rate from Table 1.12.1. The percentage time empty is not to be taken as less than 25 per cent.

12.3.4 The default coating life is to be taken as 15 years. Alternative corrosion additions may be derived using the general principles shown in Fig. 1.12.3 where an alternative coating life is specified.

12.3.5 To address the risk of pitting corrosion, the gross thickness of the bottom plating of tanks is not to be less than:

$t_{grs} = 6 + N_t (20t_{c1} + t_{c2})$

where

N_t = number of years between surveys (not to be taken as less than 5 for new builds or 2,5 for conversions)

t_{c1} and t_{c2} = are defined in 12.3.2. t_{c1} is the value for the side of the structural member within the tank.

Explanatory note:

This requirement ensures that there is sufficient bottom plating thickness remaining at thickness measurement survey so that pitting corrosion should not lead to loss of barrier integrity between inspections.

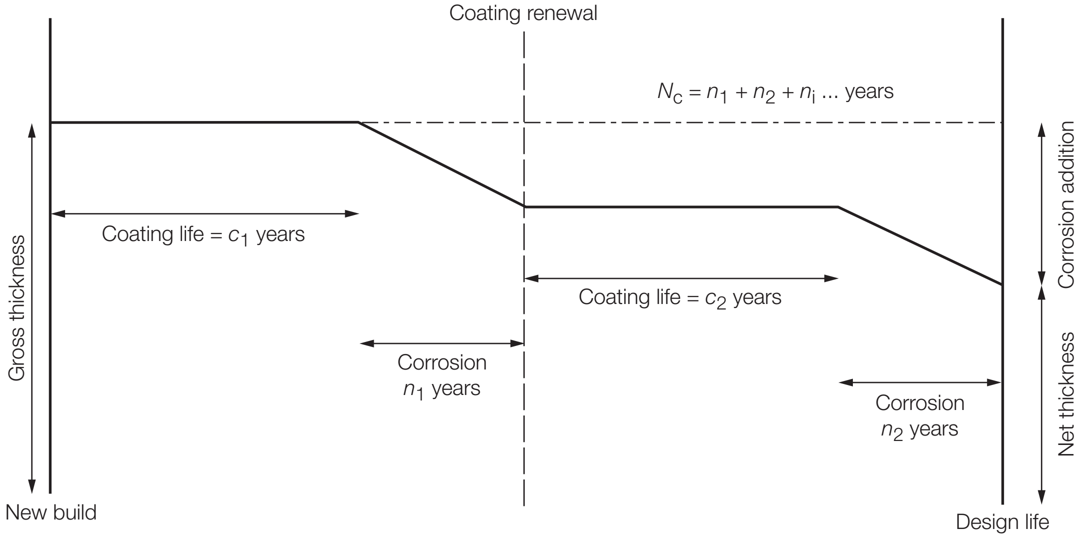


Fig. 1.12.3 Generic example unit life cycle

12.4 Scantling compliance

12.4.1 The minimum net thicknesses of structural items as required by Chapter 3 are to be rounded to the nearest 0,5 mm prior to the addition of Owner's extras or corrosion additions. The applicable corrosion additions are given in 12.3.

12.4.2 The net section modulus, moment of inertia and shear area properties of local support members are to be calculated using the net thicknesses of the attached plate, web and flange.

12.4.3 The net section properties, shear area and section modulus of primary support members are to be calculated using the net thicknesses of the attached plate, web and flange plus half of the applicable corrosion addition specified in 12.3.

12.4.4 The net scantlings described in this sub-Section are related to gross scantlings as follows:

(a) for application of the minimum thickness requirements, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in 12.3;
(b) for plating and local support members, the gross thickness and gross cross-sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in 12.3;
(c) for primary support members, the gross shear area, gross section modulus and other gross cross-sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions specified in 12.3;
(d) for application of buckling requirements, the gross thickness and gross cross-sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in 12.3.

12.4.5 Any additional thickness specified by the Owner as Owner's extra margin is not to be included when considering compliance with this Section.

12.4.6 For the subject analysis types, the corrosion applied to the gross scantlings prior to the compliance assessment is given in Table 1.12.2.

Table 1.12.2 Corrosion applied to the gross scantling for assessment

Assessment		Stress calculations	Buckling capacity calculations
Minimum thickness	Thickness	t_C	N/A
Local strength (plates, stiffeners, and hold frames)	Thickness/sectional properties Stiffness/proportions	t_C t_C	N/A t_C
Primary support members (Prescriptive)	Thickness/sectional properties Stiffness/proportions of web and flange	$0,5t_C$ t_C	N/A t_C
Strength	Global coarse mesh Local fine mesh	$0,5t_C$ t_C	t_C
Fatigue	Global coarse mesh Local fine mesh	$0,25t_C$ $0,5t_C$	N/A
Sloshing	Sloshing	t_C	t_C
Fracture	Global coarse mesh Local extremely fine mesh	$0,25t_C$ $0,5t_C$	N/A
Ultimate strength	Ultimate strength	$0,5t_C$	$0,5t_C$

NOTES
For the assessment, the gross scantling used is not to include any Owner's extra.

Section 13
Steel renewal criteria

13.1 General

13.1.1 The plans to be supplied on board the ship, *see* 2.3, are to include both the as-built and renewal thicknesses. Any Owner's extra thickness is also to be clearly indicated on the drawings. The as-built Midship Section plan provided by the Builder and carried on board the ship is to include a Table showing the minimum allowable hull girder sectional properties for the mid-tank transverse section in all cargo tanks.

13.1.2 Re-examination and additional thickness measurements are required annually where the coating condition is POOR, as defined in Pt 1, Ch 3,1.5.12.

13.1.3 Steel renewal is to be carried out when the measured thickness is less than:

$t = t_{net} + N_t (t_{c1} + t_{c2})$ mm, rounded up to the nearest 0,25 mm

For tank bottom plating:

$t = 6 + N_t (20t_{c1} + t_{c2})$ mm, rounded up to the nearest 0,25 mm

where

t_{net} = required net thickness

N_t = number of years between surveys (not to be taken as greater than 5 years or less than 1 year)

t_{c1} and t_{c2} are defined in 12.3.2.

13.2 Definitions

13.2.1 General corrosion is defined as areas where general uniform reduction of material thickness is found over an extensive area.

13.2.2 Pitting corrosion is defined as scattered corrosion spots/areas with local material reductions which are greater than the general corrosion in the surrounding area. The pitting intensity is defined in Fig. 1.13.1.

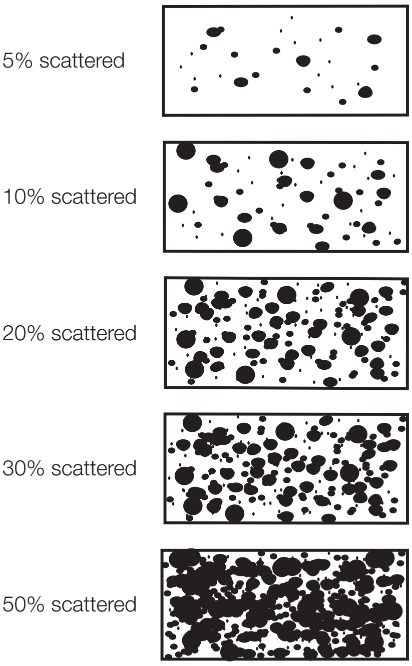


Fig. 1.13.1 Pitting intensity

13.2.3 Edge corrosion is defined as local corrosion at the free edges of plates, stiffeners, primary support members and around openings. An example of edge corrosion is shown in Fig. 1.13.2.

13.2.4 Groove corrosion is typically local material loss adjacent to weld joints along abutting stiffeners and at stiffener or plate butts or seams. An example of groove corrosion is shown in Fig. 1.13.3.

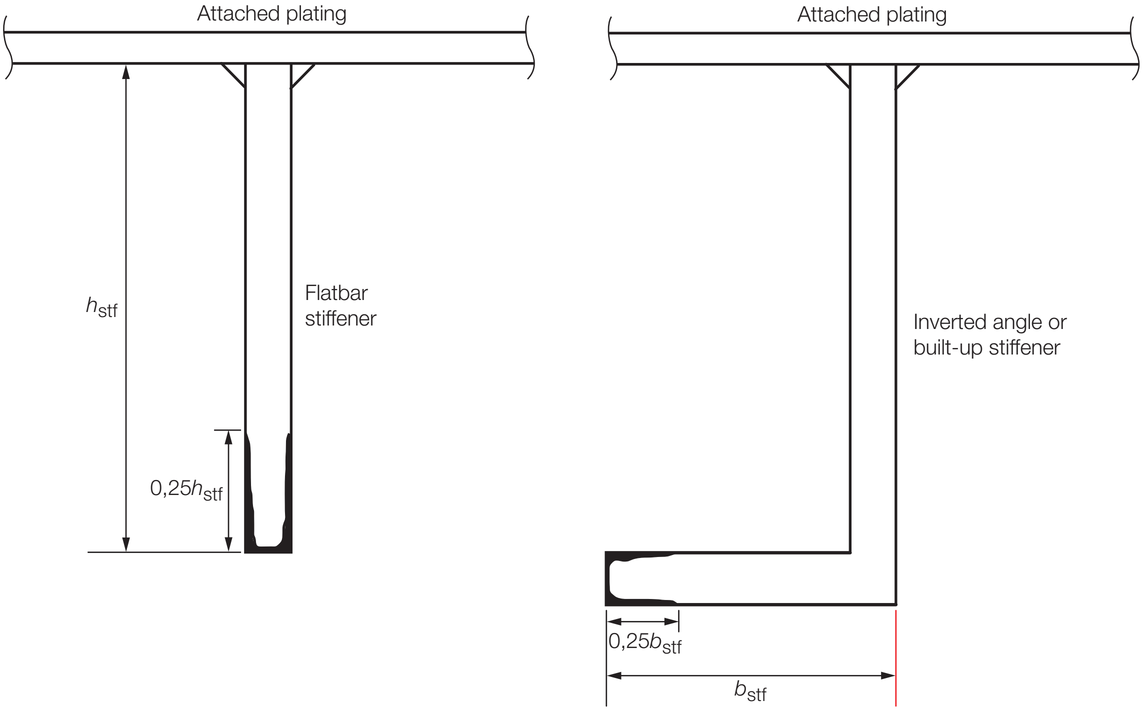


Fig. 1.13.2 Edge corrosion

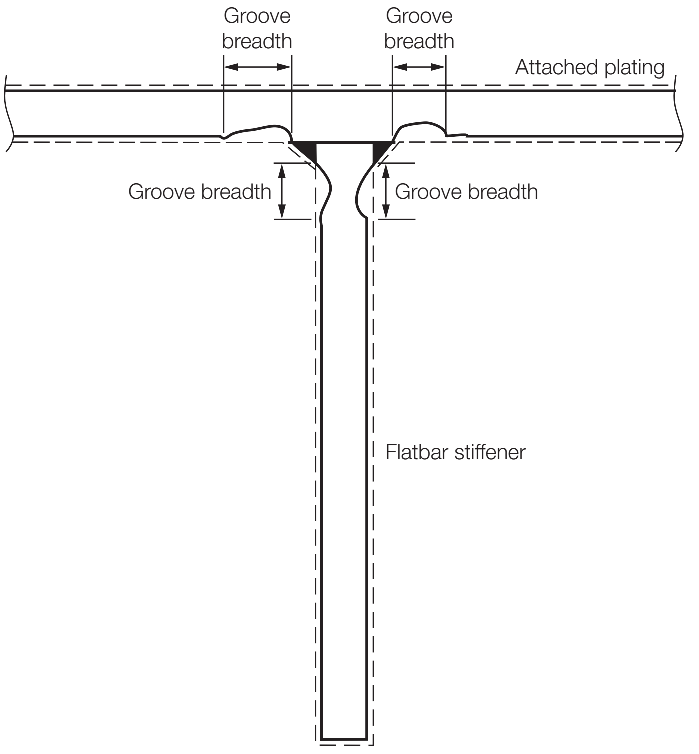


Fig. 1.13.3 Groove corrosion

13.3 Local structure

13.3.1 For local structure when general corrosion has occurred, steel renewal is required where the measured thickness is less than the renewal thickness:

$t = t_{net} + t_{c1} + t_{c2}$ mm, rounded up to the nearest 0,25 mm

where

t_{net} = required net thickness
t_{c1} and t_{c2} are defined in 12.3.2.

13.3.2 For plates with pitting intensity less than 20 per cent, *see* Fig. 1.13.1, steel renewal is required where the measured thickness of any one measurement is less than:

0,7 (as-built thickness – Owner's extra); or
1 mm less than the renewal thickness.

Steel renewal is also required where the average thickness across any cross-section in the plating is less than the renewal criteria for general corrosion given in 13.3.1.

13.3.3 Where the overall length of edge corrosion, *see* Fig. 1.13.2, is less than 25 per cent, steel renewal is required where the measured thickness is less than:

0,7 (as-built thickness – Owner's extra); or
1 mm less than the renewal thickness.

Steel renewal is also required where the average thickness across the breadth or height of the stiffener is less than the renewal criteria for general corrosion given in 13.3.1.

13.3.4 Plate edges at openings for manholes, lightening holes etc. may be below the minimum thickness given in 13.3.1, provided that:

(a) the maximum extent of the reduced plate thickness, below the minimum given in 13.3.1, from the opening edge is not more than 20 per cent of the smallest dimension of the opening and does not exceed 100 mm;
(b) rough or uneven edges may be cropped back, provided that the maximum dimension of the opening is not increased by more than 10 per cent.

13.3.5 For grooved areas, steel renewal is required where the measured thickness is less than:

0,75 (as-built thickness – Owner's extra);
0,5 mm less than the renewal thickness; or
less than 6 mm.

Members with areas of grooving greater than 15 per cent of the web height or 30 mm are to be assessed based on the criteria for general corrosion as defined in 13.3.1, using the average measured thickness across the plating/stiffener.

13.4 Hull girder section

13.4.1 The following actual hull girder sectional properties are required to be verified:

(a) vertical hull girder moment of inertia, about the horizontal axis;
(b) hull girder section modulus about the horizontal axis - at deck-at-side;
(c) hull girder section modulus about the horizontal axis - at keel;
(d) hull girder section modulus about the vertical axis - at side;
(e) hull girder vertical shear area.

13.4.2 The minimum allowable hull girder section properties are to be calculated with every member at a thickness equal to its required net minimum thickness plus half the applicable corrosion addition given in 12.3.

■ *Section 14*
Local strength and structural details

14.1 General

14.1.1 Design for local strength including helicopter landing areas and bulwarks, etc., is to comply with the requirements of Pt 4, Ch 7, as applicable.

14.1.2 Watertight and weathertight integrity and load lines are to comply with the requirements of Pt 4, Ch 8, as applicable.

14.1.3 Welding, NDE, connections, structural details and fabrication tolerances are to comply with the requirements of Pt 4, Ch 9, as applicable.

14.1.4 Anchoring and towing equipment are to comply with the requirements of Pt 4, Ch 10, as applicable.

14.1.5 Steering arrangements are to comply with the requirements of Pt 4, Ch 11, as applicable.

14.1.6 Requirements, additional to these Rules, may be imposed by the National Administration in the area of operation and/or the country of administration, as applicable.

■ *Section 15*
In-service assessment

15.1 General

15.1.1 Any damage, defect, etc., is to be reported to LR without delay, *see* Pt 1, Ch 2,1.1.7.

15.1.2 All repairs and other measures are to be agreed with LR, *see* Pt 1, Ch 2,3.4.

15.1.3 Details of an acceptable procedure for the assessment of structural defects in service are outlined in the LR *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

Section 16

Sloshing

16.1 General

16.1.1 When the partial filling of tanks is contemplated in operating conditions, the sloshing loads on tank boundaries are to be assessed in accordance with the LR *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*. Full account is to be taken of the operating requirements on station with regard to the filling, transfer and export operations for oil bulk storage tanks.

Section 17

Hull girder ultimate strength

17.1 General

17.1.1 The hull girder ultimate strength is to be assessed in accordance with the LR *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations*.

Section 18

Buckling

18.1 General

18.1.1 **Symbols**. The symbols used in this Chapter are defined as follows:

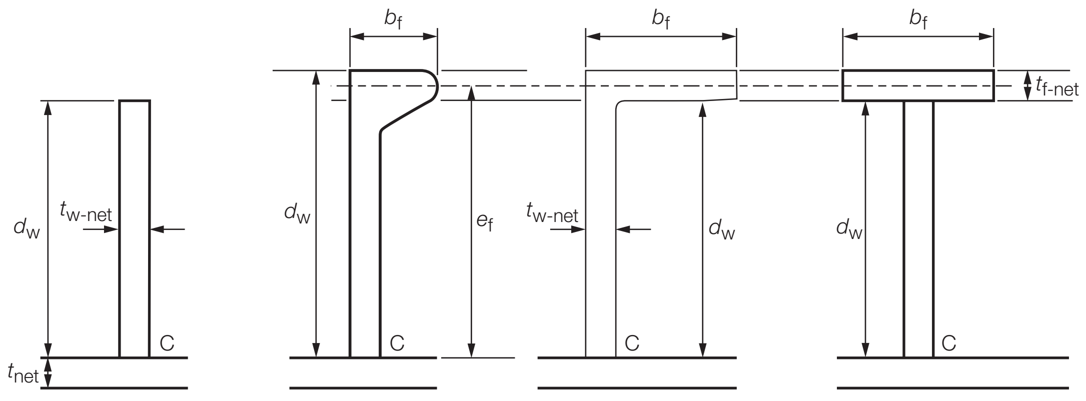
η_{allow} = allowable buckling utilisation factor, as defined in Ch 3,1.5.2
η = buckling utilisation factor, as defined in 18.2.1.1, 18.3.2.2, 18.3.3.1, 18.4.1.1 and 18.5.1.1
σ_x, σ_y = actual compressive stresses for plates, in N/mm^2
σ_x = compressive axial stress in the stiffener, in N/mm^2, in way of the midspan of the stiffener
η = buckling utilisation factor, as defined in 18.2.1.1, 18.3.2.2, 18.3.3.1, 18.4.1.1 and 18.5.1.1
τ = actual shear stress, in N/mm^2
σ_{xcr}, σ_{ycr} = critical compressive stress, in N/mm^2, as defined in 18.2.1.3
τ_{cr} = critical shear stress, in N/mm^2, as defined in 18.2.1.3
K = buckling factor, *see* Table 1.18.1
σ_E = reference stress, in N/mm^2
E = modulus of elasticity, 206 000 N/mm^2
t_{net} = net thickness of plate panel, in mm
l_a = length of the side of the plate panel, as defined in Table 1.18.1, in mm
σ_{yd} = specified minimum yield stress of the material, in N/mm^2
C_x, C_y, C_τ = reduction factors, as given in Table 1.18.1
σ_b = bending stress at the midspan of the stiffener according to 18.3.2.3, in N/mm^2
s = stiffener spacing, in mm
d_w = depth of web plate, in mm, as shown in Fig. 1.18.1
$t_{f\text{-}net}$ = net flange thickness, in mm
$t_{w\text{-}net}$ = net web thickness, in mm
b_f = flange breadth, in mm
ν = Poisson's ratio, 0,3.

18.1.2 Scope

18.1.2.1 This Section contains the methods for determination of the buckling capacity, definitions of buckling utilisation factors and other measures necessary to control buckling of plate panels, stiffeners and primary support members.

18.1.2.2 The buckling utilisation factor is to satisfy the following criteria:

$\eta \le \eta_{allow}$



NOTE
Measurements of breadth and depth are based on gross scantlings

Fig. 1.18.1 Stiffener cross-sections

18.1.2.3 For structural idealisation and definitions *see also* Section 8. The thickness and section properties of plates and stiffeners are to be taken as specified by the appropriate Rule requirements.

18.2 Buckling of plates

18.2.1 Uni-axial buckling of plates.

18.2.1.1 The buckling utilisation factor for uni-axial stress is to be taken as:

$$\eta = \frac{\sigma_x}{\sigma_{xcr}} \text{ for compressive stresses in x-direction}$$

$$\eta = \frac{\sigma_y}{\sigma_{ycr}} \text{ for compressive stresses in y-direction}$$

$$\eta = \frac{\tau}{\tau_{cr}} \text{ for shear stress}$$

18.2.1.2 Reference degree of slenderness, to be taken as:

$$\lambda = \sqrt{\frac{\sigma_{yd}}{\kappa \sigma_E}}$$

18.2.1.3 The critical stresses, σ_{xcr}, σ_{ycr} or τ_{cr}, of plate panels subject to compression or shear, respectively, is to be taken as:

$$\sigma_{xcr} = C_x \sigma_{yd}$$
$$\sigma_{ycr} = C_y \sigma_{yd}$$

$$\tau_{cr} = C_\tau \frac{\sigma_{yd}}{\sqrt{3}} .$$

18.3 Buckling of stiffeners

18.3.1 Critical compressive stress.

18.3.1.1 The buckling utilisation factor of stiffeners is to be taken as the maximum of the column and torsional buckling mode as given in 18.3.2 and 18.3.3.

Table 1.18.1 Buckling factor and reduction factor for plane plate panels *(continued)*

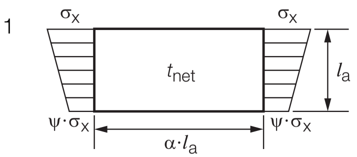
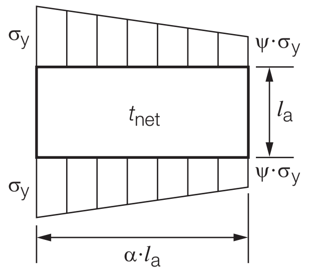
Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
1  σ_x σ_x t_{net} l_a $\psi \cdot \sigma_x$ $\psi \cdot \sigma_x$ $\alpha \cdot l_a$	$1 \geq \psi \geq 0$	$\alpha > 1$	$K = \dfrac{8,4}{\psi + 1,1}$	$C_x = 1$ for $\lambda \leq \lambda_c$ $C_x = c\left(\dfrac{1}{\lambda} - \dfrac{0,22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ where $c = (1,25 - 0,12\psi) \leq 1,25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0,88}{c}}\right)$
	$0 > \psi > -1$		$K = 7,63 - \psi\,(6,26 - 10\psi)$	
	$\psi \leq -1$		$K = 5,975\,(1 - \psi)^2$	
2  σ_y $\psi \cdot \sigma_y$ t_{net} l_a σ_y $\psi \cdot \sigma_y$ $\alpha \cdot l_a$	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = \left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2,1}{(\psi + 1,1)}$	$C_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2\,(H - R)}{\lambda^2}\right)$ where $c = (1,25 - 0,12\psi) \leq 1,25$ $R = \lambda\,(1 - \lambda/c)$ for $\lambda < \lambda_c$ $R = 0,22$ for $\lambda \geq \lambda_c$ $\lambda_c = 0,5c\left(1 + \sqrt{1 - 0,88/c}\right)$ $F = \left(1 - \left(\dfrac{K}{0,91} - 1\right) / \lambda_p^2\right) c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0,5$ and $1 \leq \lambda_p^2 \leq 3$ $c_1 = 1$ for σ_y due to direct loads (3) $c_1 = (1 - 1/\alpha) \geq 0$ for σ_y due to bending (in general) (2) $c_1 = 0$ for σ due to bending in extreme load cases (e.g. w/t.bhds.) $H = \lambda - \dfrac{2\lambda}{c\,(T + \sqrt{T^2 - 4}\,)} \geq R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
	$0 > \psi > -1$	$1 \leq \alpha \leq 1,5$	$K = \left[1 + \dfrac{1}{\alpha^2}\right]^2 \dfrac{2,1\,(1 + \psi)}{1,1} -$ $\dfrac{\psi}{\alpha^2}\,(13,9 - 10\psi)$	
		$\alpha > 1,5$	$K = \left[1 + \dfrac{1}{\alpha^2}\right]^2 \dfrac{2,1\,(1 + \psi)}{1,1} -$ $\dfrac{\psi}{\alpha^2}\,(5,87 + 1,87\alpha^2 +$ $\dfrac{8,6}{\alpha^2} - 10\psi)$	
	$\psi \leq -1$	$1 \leq \alpha \leq \dfrac{3\,(1 - \psi)}{4}$	$K = \left(\dfrac{1 - \psi}{\alpha}\right)^2 5,975$	
		$\alpha > \dfrac{3\,(1 - \psi)}{4}$	$K = \left(\dfrac{1 - \psi}{\alpha}\right)^2 3,9675 +$ $0,5375\left(\dfrac{1 - \psi}{\alpha}\right)^4 + 1,87$	

Table 1.18.1 Buckling factor and reduction factor for plane plate panels (*continued*)

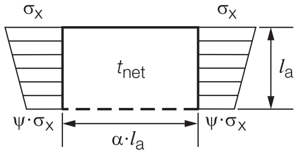
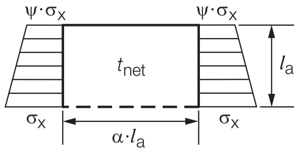
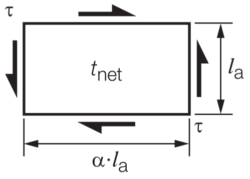
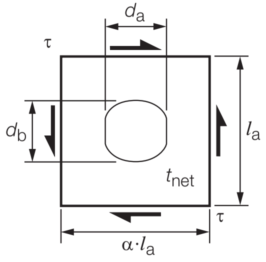
Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
3  σ_x σ_x t_{net} l_a $\psi \cdot \sigma_x$ $\psi \cdot \sigma_x$ $\alpha \cdot l_a$	$1 \geq \psi \geq 0$	$\alpha > 0$	$K = \dfrac{4\,(0{,}425 + 1/\alpha^2)}{3\psi + 1}$	$C_x = 1$ for $\lambda \leq 0{,}7$ $C_x = \dfrac{1}{\lambda^2 + 0{,}51}$ for $\lambda > 0{,}7$
	$0 > \psi \geq -1$		$K = 4\,(0{,}425 + 1/\alpha^2)\,(1 + \psi) - 5\psi\,(1 - 3{,}42\psi)$	
4  $\psi \cdot \sigma_x$ $\psi \cdot \sigma_x$ t_{net} l_a σ_x σ_x $\alpha \cdot l_a$	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left(0{,}425 + \dfrac{1}{\alpha^2}\right) \dfrac{3 - \psi}{2}$	
5  τ t_{net} l_a τ $\alpha \cdot l_a$			$K = K_\tau \sqrt{3}$	$C_\tau = 1$ for $\lambda \leq 0{,}84$ $C_\tau = \dfrac{0{,}84}{\lambda}$ for $\lambda > 0{,}84$
		$\alpha \geq 1$	$K_\tau = \left[5{,}34 + \dfrac{4}{\alpha^2}\right]$	
		$0 < \alpha < 1$	$K_\tau = \left[4 + \dfrac{5{,}34}{\alpha^2}\right]$	
6  d_a τ d_b l_a t_{net} τ $\alpha \cdot l_a$			$K = K' r$ $K' = K$ according to Case 5 $r =$ opening red. factor $r = \left(1 - \dfrac{d_a}{\alpha\, l_a}\right)\left(1 - \dfrac{d_b}{l_a}\right)$ $\dfrac{d_a}{\alpha\, l_a} \leq 0{,}7$ and $\dfrac{d_b}{l_a} \leq 0{,}7$	

Table 1.18.1 Buckling factor and reduction factor for plane plate panels (*conclusion*)

where

ψ = the ratio between smallest and largest compressive stress, as shown for Case 1-4
l_a = length, in mm, of the shorter side of the plate panel for Cases 1 and 2
l_a = length, in mm, of the side of the plate panel, as defined for Cases 3, 4, 5 and 6
α = aspect ratio of the plate panel

Edge boundary conditions:
- - - - - - - - - plate edge free
——— plate edge simply supported

NOTES
1. Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates.
2. c_1 due to bending (in general) corresponds to straight edges (uniform displacement) of a plate panel integrated in a large structure. This value is to be applied for hull girder buckling and buckling of web plate of primary support members in way of openings.
3. c_1 for direct loads corresponds to a plate panel with edges not restrained from pull-in which may result in non-straight edges.

18.3.2 **Column buckling mode**.

18.3.2.1 Stiffeners are to be verified against the column buckling mode as given in 18.3.2.2 with the allowable buckling utilisation factor, η_{allow}, *see* 18.1.2.2. Stiffeners not subjected to lateral pressure and that have a net moment of inertia, I_{net}, complying with 18.3.2.4 have acceptable column buckling strength and need not be verified against 18.3.2.2.

18.3.2.2 The buckling utilisation factor for column buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x + \sigma_b}{\sigma_{yd}}$$

where

σ_b = bending stress at the midspan of the stiffener according to 18.3.2.3, in N/mm^2.

18.3.2.3 The bending stress in the stiffener is equal to:

$$\sigma_b = \frac{M_o + M_1}{1000 Z_{net}} \text{ N/mm}^2$$

where

Z_{net} = net section modulus of stiffener, in cm^3, including effective breadth of plating according to 18.3.4.1

(a) if lateral pressure is applied to the stiffener:

Z_{net} = the section modulus calculated at flange if the lateral pressure is applied on the same side as the stiffener

Z_{net} = the section modulus calculated at attached plate if the lateral pressure is applied on the side opposite to the stiffener

(b) if no lateral pressure is applied on the stiffener:

Z_{net} = the minimum section modulus among those calculated at flange and attached plate

M_1 = bending moment, in Nmm, due to the lateral load P

$$= \frac{P\, s\, l_{stf}^2}{24} 10^3$$

P = lateral load, in kN/m^2

l_{stf} = span of stiffener, in metres, equal to spacing between primary support members

M_o = bending moment, in Nmm, due to the lateral deformation w of stiffener

$$= F_E \left(\frac{P_z w}{c_f - P_z}\right) \quad \text{where } (c_f - P_z) > 0$$

F_E = ideal elastic buckling force of the stiffener, in N

$$= \left(\frac{\pi^2}{l_{stf}^2}\right) E\, I_{net} \quad 10^{-2}$$

I_{net} = moment of inertia, in cm^4, of the stiffener including effective width of attached plating according to 18.3.4.1. I_{net} is to comply with the following requirement:

$$I_{net} \geq \frac{s\, t_{net}^3}{12} 10^{-4}$$

t_{net} = net thickness of plate flange, to be taken as the mean thickness of the two attached plate panels, in mm

P_z = nominal lateral load, in N/mm^2, acting on the stiffener due to membrane stresses, σ_x, σ_y and τ_1, in the attached plate in way of the stiffener midspan:

$$= \frac{t_{net}}{s} \left(\sigma_{xl} \left(\frac{\pi\, s}{1000 l_{stf}}\right)^2 + 2 c_y\, \sigma_y + \sqrt{2}\ \tau_1\right)$$

$$\sigma_{xl} = \sigma_x \left(1 + \frac{A_{net}}{s\, t_{net}}\right) \text{ N/mm}^2$$

$$\tau_1 = \left[\tau - t_{net} \sqrt{\sigma_{yd}\, E \left(\frac{m_1}{(1000 l_{stf})^2} + \frac{m_2}{s^2}\right)}\right] \geq 0$$

with m_1 and m_2 taken equal to

$$m_1 = 1{,}47 \qquad m_2 = 0{,}49 \text{ for } \frac{1000 l_{stf}}{s} \geq 2{,}0$$

$$m_1 = 1{,}96 \qquad m_2 = 0{,}37 \text{ for } \frac{1000 l_{stf}}{s} \geq 2{,}0$$

A_{net} = net sectional area of the stiffener without attached plating, in mm^2

c_y = factor taking into account the membrane stresses in the attached plating acting perpendicular to the stiffener's axis
= $0,5\,(1 + \psi)$ for $0 \leq \psi \leq 1$
= $\dfrac{0,5}{1 - \psi}$ for $\psi < 0$
ψ = edge stress ratio for Case 2 according to Table 1.18.1
σ_y = membrane compressive stress in the attached plating acting perpendicular to the stiffener's axis, in N/m^2
τ = shear membrane stress in the attached plating, in N/mm^2
w = deformation of stiffener, in mm
= $w_0 + w_1$
w_0 = assumed imperfection, in mm
= $\min\left[\dfrac{1000 l_{stf}}{250}, \dfrac{s}{250}, 10\right]$

For stiffeners sniped at both ends w_0 is not to be taken less than the distance from the midpoint of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating according to 18.3.4.1

w_1 = deformation of stiffener at midpoint of stiffener span due to lateral load P, in mm. In case of uniformly distributed load w_1 is to be taken as:
= $\dfrac{Ps\, l_{stf}^4}{384 \cdot E\, I_{net}}\, 10^5$
c_f = elastic support provided by the stiffener, in N/mm^2
= $F_E \dfrac{\pi^2}{l_{stf}^2} (1 + c_p)\, 10^{-6}$

$$c_p = \frac{1}{1 + \dfrac{0,91}{c_a}\left(\dfrac{12 I_{net}\, 10^4}{s\, t_{net}^3} - 1\right)}$$

$$c_a = \left[\frac{1000 l_{stf}}{2s} + \frac{2s}{1000 l_{stf}}\right]^2 \quad \text{for } l_{stf} \geq \frac{2s}{1000}$$

$$c_a = \left[1 + \left(\frac{1000 l_{stf}}{2s}\right)^2\right]^2 \quad \text{for } l_{stf} < \frac{2s}{1000}$$

18.3.2.4 Stiffeners not subjected to lateral pressure are considered as complying with the requirements of 18.3.2.2 if their net moments of inertia, in cm^4, satisfy the following requirement:

$$I_{net} \geq 100\, \frac{P_z\, l_{stf}^2}{\pi^2} \left[\frac{w_0\,(e_f - 0,5 t_{f-net})}{\eta_{allow}\, \sigma_{yd} - \sigma_x} + \frac{l_{stf}^2}{E\pi^2}\, 10^6\right]$$

where

e_f = distance from connection to plate (C as shown in Fig. 1.18.1) to centre of flange, in mm
= $(d_w - 0,5 t_{f\text{-}net})$ for bulb flats
= $(d_w + 0,5 t_{f\text{-}net})$ for angles and T bars

NOTE
Other parameters are as defined in 18.3.2.3.

18.3.3 **Torsional buckling mode**.

18.3.3.1 The torsional buckling mode is to be verified against the allowable buckling utilisation factor, η_{allow}, *see* 18.1.2.2. The buckling utilisation factor for torsional buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x}{C_T\, \sigma_{yd}}$$

where

σ_x = compressive axial stress in the stiffener, in N/mm^2, calculated at the attachment point of the stiffener to the plate, in way of the midspan of the stiffener measured along the global x-axis
C_T = torsional buckling coefficient
= 1,0 for $\lambda_T \leq 0,2$
= $\dfrac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}}$ for $\lambda_T > 0,2$
$\Phi = 0,5\,(1 + 0,21\,(\lambda_T - 0,2) + \lambda_T^2)$

Table 1.18.2 Moments of inertia

Section property	Flat bars	Bulb flats, angles and T bars
$I_{P\text{-net}}$	$\dfrac{d_w^3\, t_{w\text{-net}}}{3 \times 10^4}$	$\left(\dfrac{A_{w\text{-net}}\,(e_f - 0{,}5t_{f\text{-net}})^2}{3} + A_{f\text{-net}}\, e_f^2\right) 10^{-4}$
$I_{T\text{-net}}$	$\dfrac{d_w\, t_{w\text{-net}}^3}{3 \times 10^4}\left(1 - 0{,}63\,\dfrac{t_{w\text{-net}}}{d_\omega}\right)$	$\dfrac{(e_f - 0{,}5t_{f\text{-net}})\, t_{w\text{-net}}^3}{3 \times 10^4}\left(1 - 0{,}63\,\dfrac{t_{w\text{-net}}}{e_f - 0{,}5t_{f\text{-net}}}\right) + \dfrac{b_f\, t_{f\text{-net}}^3}{3 \times 10^4}\left(1 - 0{,}63\,\dfrac{t_{f\text{-net}}}{b_f}\right)$
$I_{\omega\text{-net}}$	$\dfrac{d_w^3\, t_{w\text{-net}}^3}{36 \times 10^6}$	for bulb flats and angles: $\dfrac{A_{f\text{-net}}\, e_f^2\, b_f^2}{12 \times 10^6}\left(\dfrac{A_{f\text{-net}} + 2{,}6A_{w\text{-net}}}{A_{f\text{-net}} + A_{w\text{-net}}}\right)$ for T bars: $\dfrac{b_f^3\, t_{f\text{-net}}\, e_f^2}{12 \times 10^6}$

λ_T = reference degree of slenderness for torsional buckling

$$= \sqrt{\frac{\sigma_{yd}}{\sigma_{ET}}}$$

σ_{ET} = reference stress for torsional buckling, in N/mm^2

$$= \frac{E}{I_{p\text{-net}}}\left(\frac{\varepsilon\, \pi^2\, I_{w\text{-net}}\, 10^{-4}}{l_t^2} + 0{,}385 I_{T\text{-net}}\right)$$

$I_{P\text{-net}}$ = net polar moment of inertia of the stiffener about point *C*, in cm^4, as shown in Fig. 1.18.1 and Table 1.18.2
$I_{T\text{-net}}$ = net St.Venant's moment of inertia of the stiffener, in cm^4, as shown in Table 1.18.2
$I_{w\text{-net}}$ = net sectorial moment of inertia of the stiffener about point *C*, in cm^6, as shown in Fig. 1.18.1 and Table 1.18.2
ε = degree of fixation

$$1+1000\sqrt{\frac{l_t^4}{\frac{3}{4}\,\pi^4\, I_{w\text{-net}}\left(\frac{s}{t_{net}^3} + \frac{4(e_f - 0{,}5t_{f\text{-net}})}{3t_{w\text{-net}}^3}\right)}}$$

l_t = torsional buckling length to be taken equal the distance between tripping supports, in metres, distance from connection to plate (*C* in Fig. 1.18.1) to centre of flange, in mm
e_f = $(d_w - 0{,}5t_{f\text{-net}})$ for bulb flats
= $(d_w + 0{,}5t_{f\text{-net}})$ for angles and T Bars
net web area, in mm^2
$A_{w\text{-net}}$ = $(e_f - 0{,}5t_{f\text{-net}})\, t_{w\text{-net}}$
net flange area, in mm^2
$A_{f\text{-net}}$ = $b_f\, t_{f\text{-net}}$

18.3.4 **Effective breadth of attached plating**.

18.3.4.1 The effective breadth of attached plating of ordinary stiffeners is to be taken as:

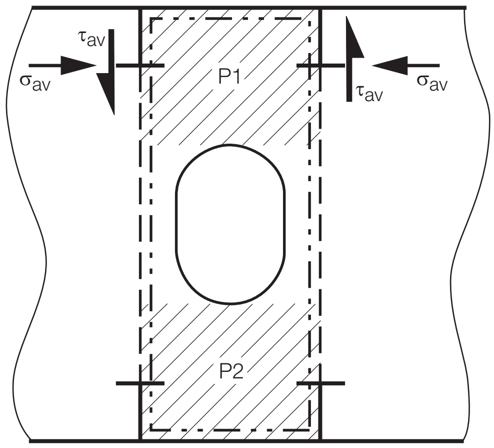
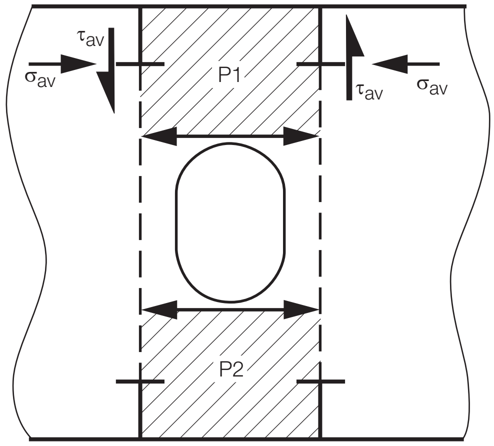
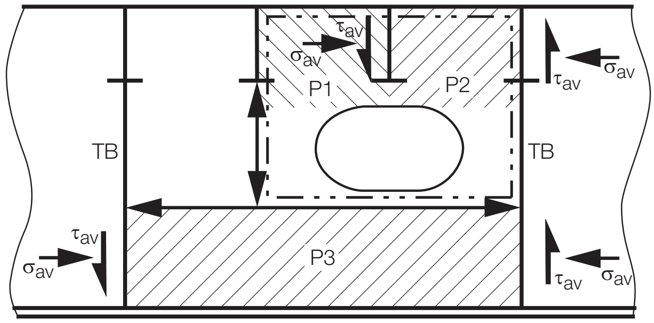
$$b_{eff} = \min(C_x\, s,\ \chi_s\, s)$$

where

$$\chi_s = 0{,}0035\left(\frac{1000 l_{eff}}{s}\right)^3 - 0{,}0673\left(\frac{1000 l_{eff}}{s}\right)^2 + 0{,}4422\left(\frac{1000 l_{eff}}{s}\right) - 0{,}0056 \le 1{,}0$$

C_x = average reduction factor for buckling of the two attached plate panels, according to Case 1 in Table 1.18.1
l_{stf} = span of stiffener, in metres, equal to spacing between primary support members
l_{eff} = effective span of stiffeners in metres
$l_{eff} = l_{stf}$ if simply supported at both ends
$l_{eff} = 0{,}6 l_{stf}$ if fixed at both ends.

Table 1.18.3 Reduction factors

Mode	C_x, C_y	C_τ
(a) Without edge reinforcements  τ_{av} σ_{av} P1 τ_{av} σ_{av} P2	Separate reduction factors are to be applied to areas P1 and P2 using Case 3, Table 1.18.1, with edge stress ratio: ψ = 1,0	A common reduction factor is to be applied to areas P1 and P2 using Case 6, Table 1.18.1 for area marked: ⬚
(b) With edge reinforcements  τ_{av} σ_{av} P1 τ_{av} σ_{av} P2	Separate reduction factors are to be applied for areas P1 and P2 using: C_x for Case 1 or C_y, for Case 2, *see* Table 1.18.1 with stress ratio ψ = 1,0	Separate reduction factors are to be applied for areas P1 and P2 using Case 5, Table 1.18.1
(c) Example of hole in web  τ_{av} σ_{av} P1 P2 τ_{av} σ_{av} TB TB τ_{av} σ_{av} P3 τ_{av} σ_{av}	Panels P1 and P2 are to be evaluated in accordance with (a). Panel P3 is to be evaluated in accordance with (b)	
NOTE Web panels to be considered for buckling in way of openings are shown shaded and numbered P1, P2, etc.		

18.4 Primary support members

18.4.1 Buckling of web plate of primary support members in way of openings.

18.4.1.1 The web plate of primary support members with openings is to be assessed for buckling, based on the combined axial compressive and shear stresses. The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels, as shown in Table 1.18.3. The buckling utilisation factor, η, is to be taken as:

$$\eta = \left(\frac{|\sigma_{av}|}{C\,\sigma_{yd}}\right)^{e} + \left(\frac{|\tau_{av}|\sqrt{3}}{C_\tau\,\sigma_{yd}}\right)^{e_\tau}$$

where

σ_{av} = average compressive stress in the area of web plate being considered according to case 1, 2 or 3 in Table 1.18.1, in N/mm^2

τ_{av} = average shear stress in the area of web plate being considered according to case 5 or 6 in Table 1.18.1, in N/mm^2

e = $1 + C^4$ exponent for compressive stress

e_τ = $1 + C\,C_\tau^2$ exponent for shear stress

C = C_x reduction factor according to Case 1 or 3, Table 1.18.1

C = C_y reduction factor according to Case 2, Table 1.18.1

C_τ = reduction factor according to Case 5 or 6, Table 1.18.1.

18.4.1.2 The reduction factors, C_x or C_y in combination with C_τ, of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 1.18.3.

18.5 Other structures

18.5.1 Struts, pillars and cross ties.

18.5.1.1 The critical buckling stress for axially compressed struts, pillars and cross ties is to be taken as the lesser of the column and torsional critical buckling stresses. The buckling utilisation factor, η, is to be taken as:

$$\eta = \frac{\sigma_{av}}{\sigma_{cr}}$$

where

σ_{av} = average axial compressive stress in the member, in N/mm^2

σ_{cr} = minimum critical buckling stress according to 18.5.1.2, in N/mm^2.

18.5.1.2 The critical buckling stress in compression for each mode is to be taken as:

$$\sigma_{cr} = \sigma_e \text{ for } \sigma_E \le 0{,}5\sigma_{yd}$$

$$\sigma_{cr} = \left(1 - \frac{\sigma_{yd}}{4\sigma_E}\right)\sigma_{yd} \text{ for } \sigma_E > 0{,}5\sigma_{yd}$$

where

σ_E = elastic compressive buckling stress, in N/mm^2, given for each buckling mode, *see* 18.5.1.3 to 18.5.1.5.

18.5.1.3 The elastic compressive column buckling stress of pillars subject to axial compression is to be taken as:

$$\sigma_E = 0{,}001 E\, f_{end} \frac{I_{net50}}{A_{pill\text{-}net50}\, l_{pill}^2} \text{ N/mm}^2$$

where

I_{net50} = net moment of inertia about the weakest axis of the cross-section, in cm^4

$A_{pill\text{-}net50}$ = net cross-sectional area of the pillar, in cm^2

f_{end} = end constraint factor:

1,0 where both ends are pinned

2,0 where one end is pinned and the other end is fixed

4,0 where both ends are fixed

A pillar end may be considered fixed when effective brackets are fitted. These brackets are to be supported by structural members with greater bending stiffness than the pillar

Column buckling capacity for cross tie shall be calculated using f_{end} equal to 2,0

l_{pill} = unsupported length of the pillar, in metres.

18.5.1.4 The elastic torsional buckling stress, σ_{ET}, with respect to axial compression of pillars is to be taken as:

$$\sigma_{ET} = \frac{G\, I_{sv\text{-}net50}}{I_{pol\text{-}net50}} + \frac{0{,}001 f_{end}\, E\, c_{warp}}{I_{pol\text{-}net50}\, l_{pill}^2} \quad \text{N/mm}^2$$

where

G = shear modulus

$= \dfrac{E}{2\,(1+\nu)}$

$I_{sv\text{-}net50}$ = net St.Venant's moment of inertia, in cm^4, *see* Table 1.18.4

$I_{pol\text{-}net50}$ = net polar moment of inertia about the shear centre of cross-section

$= I_{y\text{-}net50} + I_{z\text{-}net50} + A_{net50}\,(y_0^2 + z_0^2)$ cm^4

f_{end} = end constraint factor:
1,0 where both ends are pinned
2,0 where one end is pinned and the other end is fixed
4,0 where both ends are fixed
Elastic torsional buckling capacity for cross tie shall be calculated using f_{end} equal to 2,0

c_{warp} = warping constant, in cm^6, *see* Table 1.18.4

l_{pill} = unsupported length of the pillar, in metres

y_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see* Table 1.18.4

z_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see* Table 1.18.4

A_{net50} = net cross-sectional area, in cm^2

$I_{y\text{-}net50}$ = net moment of inertia about y-axis, in cm^4

$I_{z\text{-}net50}$ = net moment of inertia about z-axis, in cm^4.

18.5.1.5 For cross-sections where the centroid and the shear centre do not coincide, the interaction between the torsional and column buckling mode is to be examined. The elastic torsional/column buckling stress with respect to axial compression is to be taken as:

$$\sigma_{ETF} = \frac{1}{2\zeta}\left[(\sigma_E + \sigma_{ET}) - \sqrt{(\sigma_E + \sigma_{ET})^2 - 4\zeta\,\sigma_E\,\sigma_{ET}}\right]$$

where

$$\zeta = 1 - \frac{(y_0^2 + z_0^2)\,A_{net50}}{I_{pol\text{-}net50}}$$

y_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see* Table 1.18.4

z_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see* Table 1.18.4

A_{net50} = net cross-sectional area, in cm^2

$I_{pol\text{-}net50}$ = net polar moment of inertia about the shear centre of cross-section, as defined in 18.5.1.4

σ_{ET} = elastic torsional buckling stress, as defined in 18.5.1.4

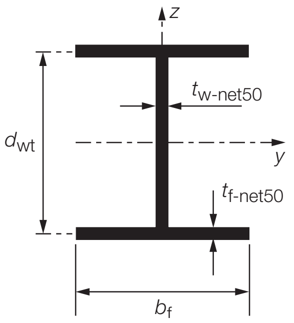
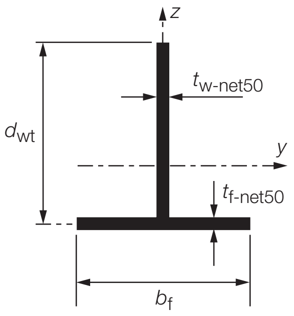
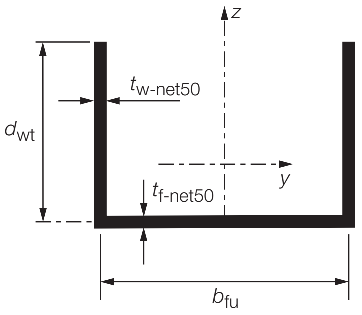
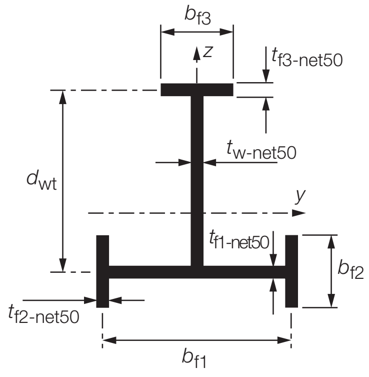
σ_E = elastic column compressive buckling stress, as defined in 18.5.1.3.

18.5.2 **Corrugated bulkheads**.

18.5.2.1 Local buckling of a unit flange of corrugated bulkheads is to be controlled according to 18.2.1.1, for Case 1, as shown in Table 1.18.1, applying stress ratio $\psi = 1{,}0$.

18.5.2.2 The overall buckling failure mode of corrugated bulkheads subjected to axial compression is to be checked for column buckling according to 18.5.1 (e.g., horizontally corrugated longitudinal bulkheads, vertically corrugated bulkheads subject to localised vertical forces). End constraint factor corresponding to pinned ends is to be applied, except for fixed end support to be used in way of stool with width exceeding two times the depth of the corrugation.

Table 1.18.4 Cross-sectional properties

Double symmetrical sections	
 z $t_{\text{w-net50}}$ d_{wt} y $t_{\text{f-net50}}$ b_{f}	$I_{\text{sv-net50}} = \dfrac{1}{3}\left(2b_{\text{f}}\,t_{\text{f-net50}}^{3} + d_{\text{w}}\,t_{\text{w-net50}}^{3}\right)10^{-4}\ \text{cm}^4$ $c_{\text{warp}} = \dfrac{d_{\text{wt}}^{2}\,b_{\text{f}}^{3}\,t_{\text{f-net50}}}{24}\,10^{-6}\ \text{cm}^6$
Single symmetrical sections	
 z $t_{\text{w-net50}}$ d_{wt} y $t_{\text{f-net50}}$ b_{f}	$I_{\text{sv-net50}} = \dfrac{1}{3}\left(b_{\text{f}}\,t_{\text{f-net50}}^{3} + d_{\text{wt}}\,t_{\text{w-net50}}^{3}\right)10^{-4}\ \text{cm}^4$ $y_0 = 0\ \text{cm}$ $z_0 = \dfrac{0{,}5d_{\text{wt}}^{2}\,t_{\text{w-net50}}}{d_{\text{wt}}\,t_{\text{w-net50}} + b_{\text{f}}\,t_{\text{f-net50}}}\,10^{-1}\ \text{cm}$ $c_{\text{warp}} = \dfrac{b_{\text{f}}^{3}\,t_{\text{f-net50}}^{3} + 4d_{\text{wt}}^{3}\,t_{\text{w-net50}}^{3}}{144}\,10^{-6}\ \text{cm}^6$
 z $t_{\text{w-net50}}$ d_{wt} y $t_{\text{f-net50}}$ b_{fu}	$I_{\text{sv-net50}} = \dfrac{1}{3}\left(b_{\text{fu}}\,t_{\text{f-net50}}^{3} + 2d_{\text{wt}}\,t_{\text{w-net50}}^{3}\right)10^{-4}\ \text{cm}^4$ $y_0 = 0\ \text{cm}$ $z_0 = \dfrac{d_{\text{wt}}^{2}\,t_{\text{w-net50}}\,10^{-1}}{2d_{\text{wt}}\,t_{\text{w-net50}} + b_{\text{f}}\,t_{\text{f-net50}}} - \dfrac{0{,}5d_{\text{wt}}^{2}\,t_{\text{w-net50}}\,10^{-1}}{d_{\text{wt}}\,t_{\text{w-net50}} + b_{\text{fu}}\,t_{\text{f-net50}}/6}\ \text{cm}$ $c_{\text{warp}} = \dfrac{b_{\text{fu}}^{2}\,d_{\text{wt}}^{3}\,t_{\text{w-net50}}\left(3d_{\text{wt}}\,t_{\text{w-net50}} + 2b_{\text{fu}}\,t_{\text{f-net50}}\right)}{12\left(6d_{\text{w}}\,t_{\text{w-net50}} + b_{\text{fu}}\,t_{\text{f-net50}}\right)}\,10^{-6}\ \text{cm}^6$
 b_{f3} z $t_{\text{f3-net50}}$ $t_{\text{w-net50}}$ d_{wt} y $t_{\text{f1-net50}}$ b_{f2} $t_{\text{f2-net50}}$ b_{f1}	$I_{\text{sv-net50}} = \dfrac{1}{3}\left(b_{\text{f1}}\,t_{\text{f1-net50}}^{3} + 2b_{\text{f2}}\,t_{\text{f2-net50}}^{3} + b_{\text{f3}}\,t_{\text{f3-net50}}^{3} + d_{\text{wt}}\,t_{\text{w-net50}}^{3}\right)10^{-4}\ \text{cm}^4$ $y_0 = 0\ \text{cm}$ $z_0 = z_{\text{s}} - \dfrac{\left(b_{\text{f3}}\,d_{\text{wt}}\,t_{\text{f3-net50}} + 0{,}5d_{\text{wt}}^{2}\,t_{\text{w-net50}}\right)10^{-1}}{d_{\text{wt}}\,t_{\text{w-net50}} + b_{\text{f1}}\,t_{\text{f1-net50}} + 2b_{\text{f2}}\,t_{\text{f2-net50}} + b_{\text{f3}}\,t_{\text{f3-net50}}}\ \text{cm}$ $c_{\text{warp}} = I_{\text{f1}}\,z_{\text{s}}^{2} + \dfrac{I_{\text{f2}}\,b_{\text{f1}}^{2}}{200} + I_{\text{f3}}\left(\dfrac{d_{\text{wt}}}{10} - z_{\text{s}}\right)^{2}\ \text{cm}^6$ $I_{\text{f1}} = \left(\dfrac{\left(b_{\text{f1}} - t_{\text{f2-net50}}\right)^{3}\,t_{\text{f1-net50}}}{12} + \dfrac{b_{\text{f2}}\,t_{\text{f2-net50}}\,b_{\text{f1}}^{2}}{2}\right)10^{-4}\ \text{cm}^4$ $I_{\text{f2}} = \dfrac{b_{\text{f2}}^{3}\,t_{\text{f2-net50}}}{12}\,10^{-4}\ \text{cm}^4$ $I_{\text{f3}} = \dfrac{b_{\text{f3}}^{3}\,t_{\text{f3-net50}}}{12}\,10^{-4}\ \text{cm}^4$ $z_{\text{s}} = \dfrac{I_{\text{f3}}\,d_{\text{wt}}}{I_{\text{f1}} + I_{\text{f3}}}\,10^{-1}\ \text{cm}$
NOTE All dimension of thickness, breadth and depth are in mm. Cross-sectional properties not covered by this Table are to be obtained by direct calculation.	

■ Section 19
Fatigue

19.1 General

19.1.1 The fatigue life is to be assessed in accordance with the *ShipRight–FOI Design, Construction and Operation Procedure for Floating Offshore Installations* and Pt 4, Ch 6,5.

19.2 Factors of safety on fatigue life

19.2.1 The factors of safety defined in Pt 4, Ch 6,5.6 are to be applied to the hull structure. Examples are given in Table 1.19.1.

Table 1.19.1 Example factors of safety on fatigue life for hull structure

Location	Inspectable/repairable?	Substantial consequence of failure?	Fatigue life factor
Bilge keel in way of ballast tanks or void spaces	Wet (OIWS)	No (no pollution)	2
Bilge keel	Wet (OIWS)	Yes (pollution)	4
LNG pump tower attachment points (top dome penetrations and bottom base support penetrations)	N0 (covered by insulation)	Yes (loss of primary and secondary barriers)	10
LNG pump tower	Dry	Yes (loss of primary and secondary barriers)	2
Bottom longitudinal stiffener end connections in way of ballast tanks or void spaces	Dry	No (no pollution)	1
Bottom longitudinal stiffener end connections	Dry	Yes (pollution)	2
Double hull hopper knuckle connection	Dry	No (no pollution)	1
Stiffened plate module supports attachment to upper deck	Dry	No	1
Lattice module supports attachment to upper deck	Dry	Yes	2
Lattice module supports attachment to upper deck with single member redundancy	Dry	No	1
Hull structure bounding membrane LNG tanks	Equivalent to wet (repair will damage insulation)	No	2
Penetrations in upper deck for LNG tank domes	No (covered by seal)	No	3

Loads

Part 10, Chapter 2

Section

1 **General**

2 **Static load components**

3 **Dynamic load components**

4 **Sloshing and impact loads**

5 **Accidental loads**

6 **Combination of loads**

7 **Environmental loads for transit/disconnected condition**

8 **Environmental loads for site-specific load scenarios**

■ *Section 1*

General

1.1 Application

1.1.1 This Section provides the design load combinations for the scantling calculations. The loads cover load scenarios for all modes of operation dividing the loads into static load components, dynamic load components, sloshing loads and impact loads.

1.1.2 The values of motions, accelerations and sloshing loads may be derived from direct calculation or obtained from model testing. These should be assessed in relation to LR's own direct calculation procedures.

1.2 Definitions

1.2.1 **Coordinate system**.

1.2.1.1 The applied coordinate system used within these Rules is defined with respect to the right-hand coordinate system.

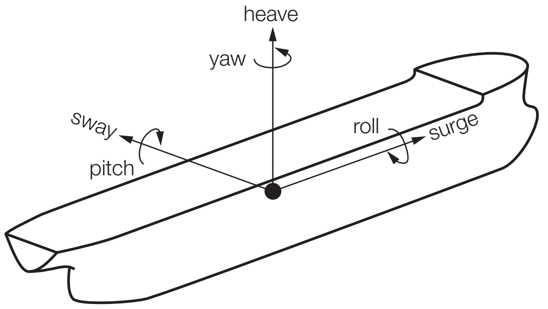
1.2.2 **Sign conventions**.

1.2.2.1 Positive motions, as shown in Fig. 2.1.1, are defined as:
(a) positive surge is translation along positive x-axis (forward);
(b) positive sway is translation along positive y-axis (towards port side of vessel);
(c) positive heave is translation along positive z-axis (upwards);
(d) positive roll is starboard down and port side up;
(e) positive pitch is bow down and stern up;
(f) positive yaw is bow rotating towards port side of vessel and stern towards starboard side.

1.2.2.2 Positive accelerations are defined as:
(a) positive longitudinal acceleration is acceleration along positive x-axis (forward);
(b) positive transverse acceleration is acceleration along positive y-axis (towards port side of vessel);
(c) positive vertical acceleration is acceleration along positive z-axis (upwards).

1.2.2.3 The sign convention of positive vertical hull girder shear force is shown in Fig. 2.1.2.

1.2.2.4 The sign conventions of positive hull girder bending moments are shown in Fig. 2.1.3 and Fig. 2.1.4, and are defined as:
(a) positive vertical bending moment is a hogging moment and negative vertical bending moment is a sagging moment;
(b) positive horizontal bending moment is tension on the starboard side and compression on the port side.



NOTE
This figure shows the rotation axis and not the coordinate system

Fig. 2.1.1 Definition of positive motions

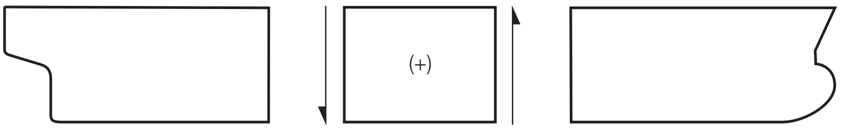


Fig. 2.1.2 Positive vertical shear force

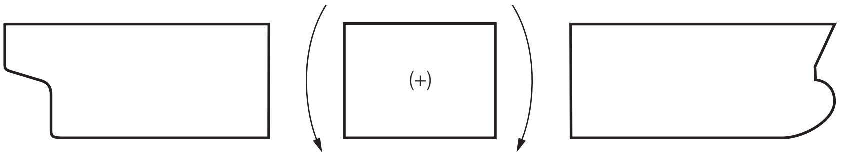


Fig. 2.1.3 Positive vertical bending moment

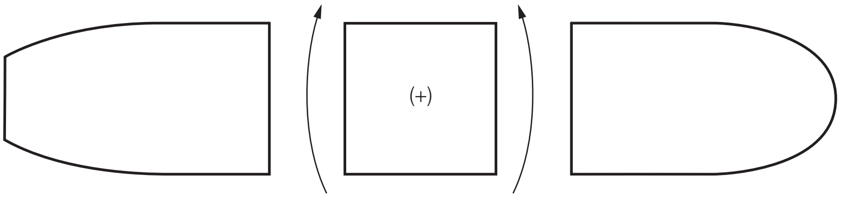


Fig. 2.1.4 Positive horizontal bending moment

1.2.3 **Density**.

1.2.3.1 The density is not to be taken as less than minimum density value, as defined in Table 2.1.1.

Table 2.1.1 Minimum density of liquid for strength and fatigue assessment

Liquid	Scantling and strength	Fatigue	Sloshing	Ultimate strength
Cargo oil	The greater of 1,025 t/m^3 or actual	Mean	The greater of 1,025 t/m^3 or actual	The greater of 1,025 t/m^3 or actual
Ballast water	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3
Sea-water, ρ_{sw}	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3
Condensate	The greater of 1,025 t/m^3 or actual	Mean	The greater of 1,025 t/m^3 or actual	The greater of 1,025 t/m^3 or actual

Section 2

Static load components

2.1 Symbols

L = Rule length, in metres, as defined in Pt 4, Ch 1,5
B = moulded breadth, in metres, as defined in Pt 4, Ch 1,5
D = moulded depth, in metres, as defined in Pt 4, Ch 1,5
C_{wv} = wave coefficient, as defined in 3.1
C_b = block coefficient, as defined in Pt 4, Ch 1,5
ρ = density, tonnes/m^3, as defined in 1.2.3
g = acceleration due to gravity, 9,81 m/s^2
$M_{sw\text{-}perm\text{-}sea}$ = permissible hull girder hogging and sagging still water bending moment envelopes for transit condition, in kNm
$M_{sw\text{-}perm\text{-}oper}$ = permissible hull girder hogging and sagging still water bending moment envelopes for operational condition, in kNm
$M_{sw\text{-}perm\text{-}maint}$ = permissible hull girder hogging and sagging still water bending moment envelopes for inspection/maintenance condition, in kNm
$Q_{sw\text{-}perm\text{-}sea}$ = permissible hull girder positive and negative still water shear force limits for transit condition, in kN
$Q_{sw\text{-}perm\text{-}oper}$ = permissible hull girder positive and negative still water shear force limits for operational condition, in kN
$Q_{sw\text{-}perm\text{-}maint}$ = permissible hull girder positive and negative still water shear force limits for inspection/maintenance condition, in kN
B_{local} = local breadth at T_{sc} at the mid-length of the tank under consideration, in metres
l_{tk} = length of cargo tank under consideration, in metres
T_{sc} = deep load draught, in metres, is the maximum draught on which the scantlings are based
V_{CT} = volume of centreline cargo tank under consideration, in m^3
V_{ST} = volume of side cargo tank under consideration, in m^3.

2.2 Static hull girder loads

2.2.1 Permissible hull girder still water bending moment and shear force.

2.2.1.1 The designer is to provide the permissible hull girder hogging and sagging still water bending moment limits for the sea-going or transit condition, $M_{sw\text{-}perm\text{-}sea}$, operational condition, $M_{sw\text{-}perm\text{-}oper}$, and inspection/maintenance condition, $M_{sw\text{-}perm\text{-}maint}$.

2.2.1.2 The designer is to provide the permissible hull girder positive and negative still water shear force limits for transit or sea-going condition, $M_{sw\text{-}perm\text{-}sea}$, operational condition, $Q_{sw\text{-}perm\text{-}oper}$, and inspection/maintenance condition, $Q_{sw\text{-}perm\text{-}maint}$.

2.2.1.3 The permissible hull girder still water bending moment and shear force limits are to be given at each transverse bulkhead in the cargo area, at the middle of cargo tanks and at significant structural discontinuities, including internal turrets.

2.2.1.4 The permissible hull girder still water bending moment envelope is given by linear interpolation between values at the longitudinal position given in 2.2.1.3.

2.2.1.5 The permissible hull girder still water bending moment and shear force envelopes are to be included in the loading manual as required in Pt 4, Ch 3,1.3 and 1.4.

2.2.2 **New build**.

2.2.2.1 Loadings patterns representative of the loading conditions for all modes of operation are to be assessed considering those cases which will induce the largest forces in the hull structure.

2.2.2.2 The static loading conditions to be used in combinations with the applicable dynamic loads in Section 6 should be appropriate for the intended operation of the unit. In general, they should include:

- homogeneous full load;
- emergency ballast;
- 'chequer-board' loading;
- all cargo tanks full with any two adjacent cargo tanks empty (this is to allow repair of any tank boundary whilst in service); and
- all cargo tanks empty with any one cargo tank full;
- most onerous partial loading conditions as applicable.

2.2.3 **Conversions and redeployments**.

2.2.3.1 The loading conditions should be as for new build units, *see* 2.2.2, suitably modified to take account of the following:

- Loading limitations previously assigned prior to conversion/redeployment.
- Where the loading conditions defined for new build units are too restrictive or too onerous.

2.3 Local static loads

2.3.1 **General**.

2.3.1.1 The following static loads are to be considered, as appropriate:

(a) static sea pressure;
(b) static tank pressure;
(c) tank overpressure, in addition to the static tank pressure when appropriate;
(d) static deck load;
(e) accidental pressure.

2.3.2 **Static pressure**.

2.3.2.1 The static pressures for the static loads defined in 2.3.1.1 are given in Table 2.2.1.

2.3.3 **Static deck loads from heavy units**.

2.3.3.1 The scantlings of structure in way of heavy units of cargo and equipment are to consider gravity forces acting on the mass. The load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, F_{stat}, is to be taken as:

$F_{\text{stat}} = m_{\text{un}}\, g$ kN

where

m_{un} = mass of unit, in tonnes.

Table 2.2.1 Static load pressures

Load cases		Static pressure, in kN/m^2
(a)	Static sea pressure	$P_{hys} = \rho_{sw}\, g\, (T_{LC} - z)$
(b)	Static tank pressure	$P_{in\text{-}tk} = \rho\, g\, z_{top}$
(c)	Static tank pressure + overpressure	$P_{in\text{-}air} = \rho_{sw}\, g\, z_{air}$ $P_{in\text{-}test} = \max\,(\rho_{sw}\, g\, z_{test},\ \rho_{sw}\, g\, z_{top} + P_{valve})$
(d)	Static deck pressure	$P_{stat} = P_{deck}$
(e)	Accidental pressure	$P_{in\text{-}flood} = \rho_{sw}\, g\, z_{fd}$

Symbols

z = vertical coordinate of load point, in metres, and is not to be greater than T_{LC}, *see* Fig. 2.2.2
ρ_{sw} = density of sea-water, 1,025 tonnes/m^3
T_{LC} = draught in the loading condition being considered, in metres
z_{top} = vertical distance from highest point of tank, excluding small hatchways, to the load point, *see* Fig. 2.2.2, in metres
z_{air} = vertical distance from top of air pipe or overflow pipe to the load point, whichever is the lesser, *see* Fig. 2.2.2, in metres
= $z_{top} + h_{air}$
h_{air} = height of air pipe or overflow pipe, in metres, is not to be taken less than 0,76 m above highest point of tank, excluding small hatchways. For tanks with tank top below the weather deck, the height of air pipe or overflow pipe is not to be taken less than 0,76 m above deck at side, unless a lesser height is approved by the Flag Administration. *See also* Fig. 2.2.2
z_{fd} = vertical distance from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations or to freeboard deck if the damage waterline is not given, in metres
z_{test} = vertical distance to the load point is to be taken as defined in Table 2.2.2
P_{valve} = setting of pressure relief valve, if fitted, is not to be taken less than 25 kN/m^2
P_{deck} = uniformly distributed pressure on lower decks and decks within superstructures, including platform decks in the main engine room and for other spaces with heavy machinery components, in kN/m^2. P_{deck} is not to be taken less than 16 kN/m^2

NOTE
The added overpressure due to sustained liquid through the air pipe or overflow pipe in the case of overfilling, P_{drop}, is to be taken as 25 kN/m^2. Additional calculations may be required where piping arrangements may lead to a higher pressure drop, e.g. long pipes or arrangements such as bends and valves.

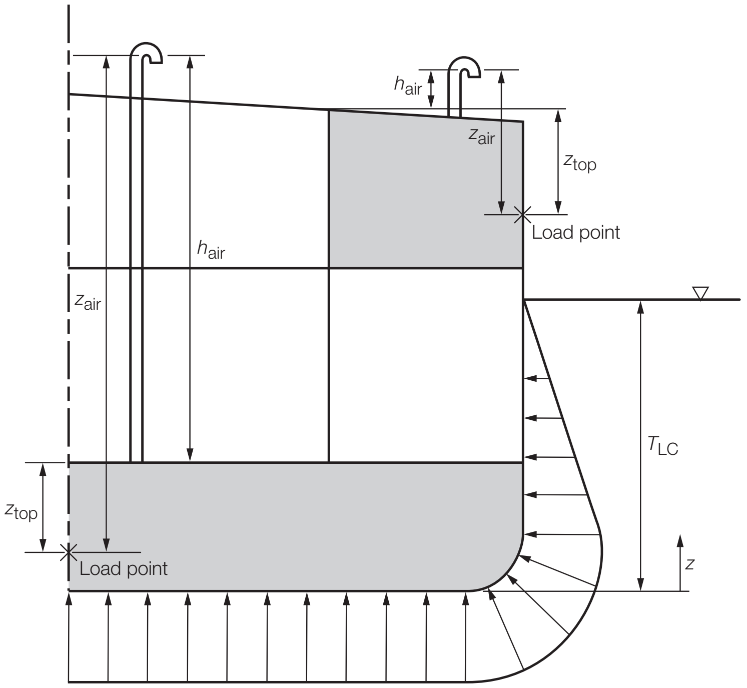


Fig. 2.2.2 Static sea pressure, pressure-heads and distances of static tank pressure

Table 2.2.2 Testing load height

Compartment or structure to be tested	Testing load height, in metres
Cargo tanks and other tanks designed for liquid filling, including double bottom tanks, hopper side tanks, topside tanks, double side tanks, deep tanks, fuel oil bunkers, slop tanks, fresh water tanks, lube oil tanks, fore and after peaks used as tanks and/or fitted with air pipe. Cofferdams	The greater of the following: $z_{test} = z_{top} + h_{air}$ $z_{test} = z_{top} + 2{,}4$ $z_{test} = z_{top} + z_{pv}$
Fore and aft peaks not used as tanks and not fitted with air pipe	To be tested for tightness (*see* Note)
Watertight doors below freeboard deck	To be tested for tightness (*see* Note)
Chain locker	$z_{test} = z_{top}$
Ballast ducts	Testing load height corresponding to ballast pump maximum pressure
Symbols are as defined in Table 2.2.1	
z_{ml} = Z coordinate, in metres, of the margin line z_h = Z coordinate, in metres, of the top of hatch z_{pv} = equivalent head of pressure safety valve, in metres = $10P_{pv}$ P_{pv} = setting pressure, in bar, of pressure safety valve where applicable	
NOTE When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.	

■ *Section 3*
Dynamic load components

3.1 Symbols

L = Rule length, in metres, as defined in Pt 4, Ch 1,5
B = moulded breadth, in metres, as defined in Pt 4, Ch 1,5
D = moulded depth, in metres, as defined in Pt 4, Ch 1,5
C_b = block coefficient, as defined in Pt 4, Ch 1,5
C_{wv} = wave coefficient to be taken as:

$$= 0{,}0412L + 4{,}0 \quad \text{for } L < 90$$

$$= 10{,}75 - \left(\frac{300 - L}{100}\right)^{\frac{3}{2}} \quad \text{for } 90 \le L \le 300$$

$$= 10{,}75 \quad \text{for } 300 < L \le 350$$

$$= 10{,}75 - \left(\frac{L - 350}{150}\right)^{\frac{3}{2}} \quad \text{for } 350 < L \le 500$$

GM = metacentric height, in metres, as defined in 3.2.3.1
k_r = roll radius of gyration, in metres, as defined in 3.2.3.1
f_{bk} = 1,2 for units without bilge keel
1,0 for units with bilge keel
T_θ = roll period, in seconds, as defined in 3.5.3.1
θ = roll amplitude, in degrees, as defined in 3.5.3.2
T_φ = pitch period, in seconds, as defined in 3.5.3.1
φ = pitch amplitude, in degrees, as defined in 3.5.3.2
$R_{roll} = z - \left(\frac{D}{4} + \frac{T_{LC}}{2}\right)$ or $z - \left(\frac{D}{2}\right)$, whichever is the greater, in metres

R_{pitch} = pitch radius and is to be taken as the greater of $z - \left(\frac{D}{4} + \frac{T_{LC}}{2}\right)$ or $z - \left(\frac{D}{2}\right)$, in metres

$f_{\text{T}} = \dfrac{T_{\text{LC}}}{T_{\text{sc}}}$

T_{sc} = deep load draught, in metres

T_{LC} = draught in the loading condition being considered, in metres

a_0 = common acceleration parameter, as defined in 3.6.2.1

a_{v} = envelope vertical acceleration, in m/s^2, as defined in 3.6.3.1, at tank centre of gravity

a_{t} = envelope transverse acceleration, in m/s^2, as defined in 3.6.4.1, at tank centre of gravity

a_{lng} = envelope longitudinal acceleration, in m/s^2, as defined in 3.6.5.1, at tank centre of gravity

a_{heave} = vertical acceleration due to heave, is to be taken as:

$= a_0\, g \quad \text{m/s}^2$

$a_{\text{pitch-z}}$ = vertical acceleration due to pitch, is to be taken as:

$$= \left(0{,}3 + \frac{L}{325}\right) \varphi \left(\frac{\pi}{180}\right)\left(\frac{2\pi}{T_\varphi}\right)^2 |x - 0{,}45L| \quad \text{m/s}^2$$

$a_{\text{roll-z}}$ = vertical acceleration due to roll, is to be taken as:

$$= 1{,}2\theta \left(\frac{\pi}{180}\right)\left(\frac{2\pi}{T_\theta}\right)^2 |y| \quad \text{m/s}^2$$

a_{sway} = transverse acceleration due to sway and yaw, is to be taken as:

$= 0{,}3g\, a_0 \quad \text{m/s}^2$

$a_{\text{roll-y}}$ = transverse acceleration due to roll, is to be taken as:

$$= \theta \left(\frac{\pi}{180}\right)\left(\frac{2\pi}{T_\theta}\right)^2 R_{\text{roll}} \quad \text{m/s}^2$$

a_{surge} = longitudinal acceleration due to surge, is to be taken as:

$= 0{,}2g\, a_0 \quad \text{m/s}^2$

$a_{\text{pitch-x}}$ = longitudinal acceleration due to pitch, is to be taken as:

$$= \varphi \left(\frac{\pi}{180}\right)\left(\frac{2\pi}{T_\varphi}\right)^2 R_{\text{pitch}} \quad \text{m/s}^2$$

ρ = density, tonnes/m^3, as defined in 1.2.3

g = acceleration due to gravity, 9,81 m/s^2

x = longitudinal coordinate of load point under consideration, in metres

y = transverse coordinate of load point under consideration, in metres

z = vertical coordinate of load point under consideration, in metres

x_0 = longitudinal coordinate of reference point, for dynamic tank pressures is to be taken as the middle of the tank length at the top of the tank, in metres

y_0 = transverse coordinate of reference point, for dynamic tank pressures is to be taken as the middle of the tank breadth at the top of the tank, in metres

z_0 = vertical coordinate of reference point, for dynamic tank pressures is to be taken as the highest point in the tank, in metres

f_{prob} = probability factor, as defined in 3.4, as appropriate

$f_{\text{FOI-pitch}}$ = environmental FOI factor due to pitch motion, as defined in 3.3.2 and 3.5.3

$f_{\text{FOI-av}}$ = environmental FOI factor due to vertical acceleration, as defined in 3.3.2 and 3.6.3

$f_{\text{FOI-at}}$ = environmental FOI factor due to transverse acceleration, as defined in 3.3.2 and 3.6.4

$f_{\text{FOI-alng}}$ = environmental FOI factor due to longitudinal acceleration, as defined in 3.3.2 and 3.6.5

$f_{\text{FOI-Mwv}}$ = environmental FOI factor due to vertical wave bending moment, as defined in 3.3.2 and 3.7.1

$f_{\text{FOI-Mwv-h}}$ = environmental FOI factor due to horizontal wave bending moment, as defined in 3.3.2 and 3.7.1

$f_{\text{FOI-Qwv}}$ = environmental FOI factor due to vertical wave shear force, as defined in 3.3.2 and 3.7.2

$f_{\text{FOI-Pex-dyn}}$ = environmental FOI factor due to dynamic wave pressure, as defined in 3.3.2 and 3.8.2.

3.2 General

3.2.1 Basic components.

3.2.1.1 Formulae for unit loads, motions and accelerations are given in this sub-Section. Values calculated in accordance with the *ShipRight – FOI procedure* may be used instead.

3.2.1.2 Formulae for the envelope value of the basic dynamic load components are also given. The basic load components are:
(a) vertical wave bending moment and shear force;
(b) horizontal wave bending moment;
(c) dynamic wave pressure;
(d) dynamic tank pressures.

3.2.2 Envelope load values.

3.2.2.1 The envelope loads for scantling requirements and strength assessment are based on the specific return period given in Table 2.3.3.

3.2.3 Metacentric height and roll radius of gyration for FPSO.

3.2.3.1 The metacentric height, *GM*, and roll radius of gyration, k_r, should be calculated for typical loading conditions as indicated in Table 2.3.1. For the initial design of units storing oil in bulk (e.g., FPSOs), the values in Table 2.3.1 may be used. The values in Table 2.3.1 for deep draught condition may be used for the initial design of units for the flooded load scenario, *see* 5.1.

Table 2.3.1 ***GM* and k_r**

Condition	T_{LC}	*GM*	k_r
Deep draught condition, usually a full load condition	above $0{,}9T_{SC}$	$0{,}12B$	$0{,}35B$
Partial load draught condition, usually a part load-part ballast condition	$0{,}6T_{SC}$	$0{,}24B$	$0{,}40B$
Light draught condition, usually a ballast condition	$0{,}5T_{SC}$	$0{,}33B$	$0{,}45B$
NOTE Values for intermediate draughts may be calculated by linear interpolation.			

3.3 Environmental FOI factors (EFF)

3.3.1 The environmental FOI factors are used to derive the dynamic load components for the intended site-specific condition and for the transit or sea-going condition.

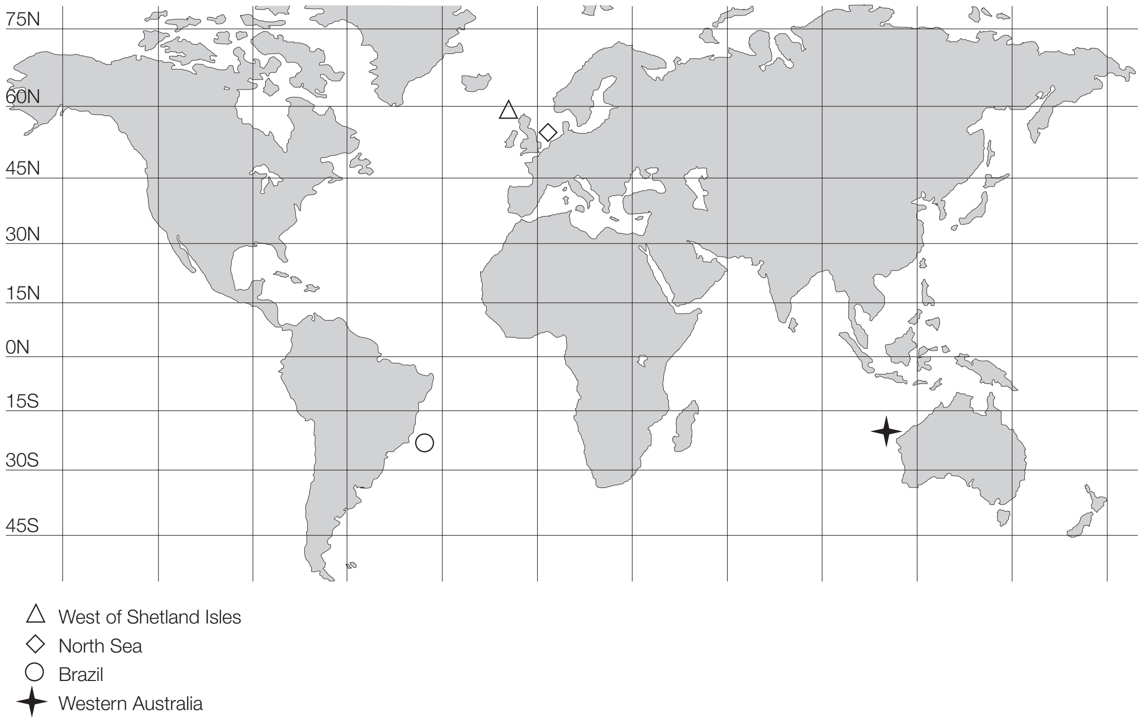
3.3.2 For initial design purposes, the environmental FOI factors considering motion are specified in Table 2.3.2. For sites not included in Table 2.3.2, the factors are to be calculated in accordance with the *ShipRight – FOI* procedure.

3.3.3 The EFFs for the operational condition may be used for the initial design of units for the inspection/maintenance case. The EFFs for the deep draught for the operational condition may be used for the initial design of units for the flooded case.

Table 2.3.2 Environmental FOI factors (EFF)

Size and mooring	Site specific condition, *see* Note 2	Draught	f_{FOI}	f_{FOI}	f_{FOI}	f_{FOI}	f_{FOI}	f_{FOI}	f_{FOI}	$f_{\text{FOI-Pex-dyn}}$, *see* Note 1		
			Pitch	a_v	a_t	a_{lng}	M_{wv}	$M_{wv\text{-}h}$	Q_{wv}	at, and aft of, midship	at 0,85*L*	at FP
Aframax Weather vaning	Unrestricted worldwide (Transit or sea-going)	N/A	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
	West of Shetland Is.	Deep Light	1,3 1,3	0,8 0,8	1,2 1,5	1,4 1,2	1,7 1,3	0,8 1,0	2,0 2,0	1,0 1,0	1,2 1,0	1,6 1,6
	North Sea	Deep Light	1,2 1,2	0,5 0,7	1,2 1,5	1,4 1,2	1,6 1,2	0,8 1,0	1,75 1,75	0,75 1,0	1,0 1,0	1,6 1,6
	Brazil	Deep Light	0,6 0,6	0,5 0,5	1,0 1,65	0,65 0,6	0,75 0,5	0,5 1,0	0,75 0,8	0,5 0,8	0,5 0,75	0,8 0,75
	Western Australia (non-cyclonic)	Deep Light	0,5 0,5	0,5 0,5	0,65 0,75	0,6 0,5	0,65 0,5	0,55 0,55	0,7 0,7	0,5 0,5	0,5 0,5	0,75 0,7
VLCC Weather vaning	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA
Aframax Spread moored	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA
VLCC Spread moored	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA

NOTES
1. Values at intermediate locations may be calculated by linear interpolation.
2. The geographic locations of the sites at which long term environmental data has been used to derive the site-specific EFFs are shown as follows:



TBA: Factor will be advised by LR upon request.

3.4 Probability factor, f_{prob}

3.4.1 The probability factor f_{prob} adjusts the global and local load components to account for the vessel's operational condition and the appropriate design return period to be used for each operational condition. These values should normally be defined by direct calculation, using an appropriate heading analysis. However, the following values may be assumed for the initial design studies.

3.4.2 The probability factor for the assessments is to be taken as specified in Table 2.3.3.

Table 2.3.3 Probability factor, f_{prob}

Operational condition	Transit or sea-going	Transit under tow	Normal on-site operation	Inspection/ maintenance	Accidental
Return Period	25 years	1 year	100 years	100 years	1 year
f_{prob}	1,0	0,8 (*see* Note 1)	1,0	1,0 (*see* Note 2)	0,8
Environment	World-wide	World-wide	Site-specific	Site-specific	Site-specific

NOTES
1. A reduced factor based on a 10 year return period and seasonal environmental data may be used for the transit route. f_{prob} is not to be taken as less than 0,5.
2. A reduced factor based on seasonal site-specific loads may be used, but f_{prob} is not to be taken as less than 0,5.
3. The probability factors for scantling and strength assessments are to be assessed in accordance with the LR *ShipRight – FOI Design, Construction and Operation Procedure for Floating Offshore Installations* procedures.

3.5 Motions

3.5.1 **General**.

3.5.1.1 The envelope values for unit motions are to be taken at the specific return period specified in Table 2.3.3.

3.5.2 **Roll Motion**.

3.5.2.1 The roll period, T_θ, is to be taken as:

$$T_\theta = \frac{2{,}3\pi\, k_r}{\sqrt{g\, GM}} \text{ seconds}$$

3.5.2.2 The roll amplitude, θ, is to be taken as:

$$\theta = \frac{9000\,(1{,}25 - 0{,}025 T_\theta)\, f_{bk}}{(B + 75)\,\pi} \text{ degrees}$$

3.5.3 **Pitch motion**.

3.5.3.1 The characteristic pitch period, T_φ, is to be taken as:

$$T_\varphi = \sqrt{\frac{2\pi\,\lambda_\varphi}{g}} \text{ seconds}$$

where

$\lambda_\varphi = 0{,}6\,(1 + f_T)\,L$

3.5.3.2 The pitch amplitude, φ, is to be taken as:

$$\varphi = 1350 f_{\text{FOI-pitch}} L^{-0,94} [1 + F_n^{1,2}] \text{ degrees}$$

where

F_n = is the non-dimensional Froude number and is defined as:

$$F_n = \frac{0,514V}{\sqrt{g L_{\text{wl}}}}$$

where

V = is the vessel speed, in knots

L_{wl} = is the length on the waterline at the load case draught, in metres.

3.6 Accelerations

3.6.1 **General**.

3.6.1.1 The envelope values for combined translational accelerations due to motion in six degrees of freedom are given. The transverse and longitudinal components of acceleration include the component of gravity due to roll and pitch.

3.6.2 **Common acceleration parameter**.

3.6.2.1 The common acceleration parameter, a_0, is to be taken as:

$$a_0 = (1,58 - 0,47C_b)\left(\frac{2,4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right)$$

3.6.3 **Vertical acceleration**.

3.6.3.1 The envelope vertical acceleration, a_v, at any position, is to be taken as:

$$a_v = f_{\text{prob}} f_{\text{FOI-av}} \sqrt{a_{\text{heave}}^2 + a_{\text{pitch-z}}^2 + a_{\text{roll-z}}^2} \quad \text{m/s}^2$$

3.6.4 **Transverse acceleration**.

3.6.4.1 The envelope transverse acceleration, a_t, at any position, is to be taken as:

$$a_t = f_{\text{prob}} f_{\text{FOI-at}} \sqrt{a_{\text{sway}}^2 + (g \sin\theta + a_{\text{roll-y}})^2} \quad \text{m/s}^2$$

3.6.5 **Longitudinal acceleration**.

3.6.5.1 The envelope longitudinal acceleration, a_{lng}, at any position, is to be taken as:

$$a_{\text{lng}} = 0,7 f_{\text{prob}} f_{\text{FOI-alng}} \sqrt{a_{\text{surge}}^2 + \left(\frac{L}{325}(g \sin\varphi + a_{\text{pitch-x}})\right)^2} \quad \text{m/s}^2$$

3.7 Dynamic hull girder loads

3.7.1 **Vertical and horizontal wave bending moments**.

3.7.1.1 The envelope hogging vertical wave bending moment, $M_{\text{wv-hog}}$, and sagging vertical wave bending moment, $M_{\text{wv-sag}}$, and horizontal wave bending moment, $M_{\text{wv-h}}$, are to be taken as:

- Vertical wave bending moment

$$M_{\text{wv-hog}} = f_{\text{prob}} f_{\text{FOI-Mwv}} 0,19 f_{\text{wv-v}} C_{\text{wv}} L^2 B C_b \quad \text{kNm}$$

$$M_{\text{wv-sag}} = -f_{\text{prob}} f_{\text{FOI-Mwv}} 0,11 f_{\text{wv-v}} C_{\text{wv}} L^2 B (C_b + 0,7) \quad \text{kNm}$$

- Horizontal wave bending moment

$$M_{\text{wv-h}} = f_{\text{prob}}\, f_{\text{FOI-Mwv-h}} \left(0{,}3 + \frac{L}{2000}\right) f_{\text{wv-h}}\, C_{\text{wv}}\, L^2\, T_{\text{LC}} + C_{\text{b}} \quad \text{kNm}$$

where

$f_{\text{wv-v}}$, $f_{\text{wv-h}}$ = distribution factors for vertical and horizontal wave bending moments along the vessel length, to be taken as:
= 0,0 at A.P.
= 1,0 for 0,4*L* to 0,65*L* from A.P.
= 0,0 at F.P.
intermediate values to be obtained by linear interpolation, *see* Fig. 2.3.1
f_{prob} = probability factor is defined in Table 2.3.3, as appropriate.

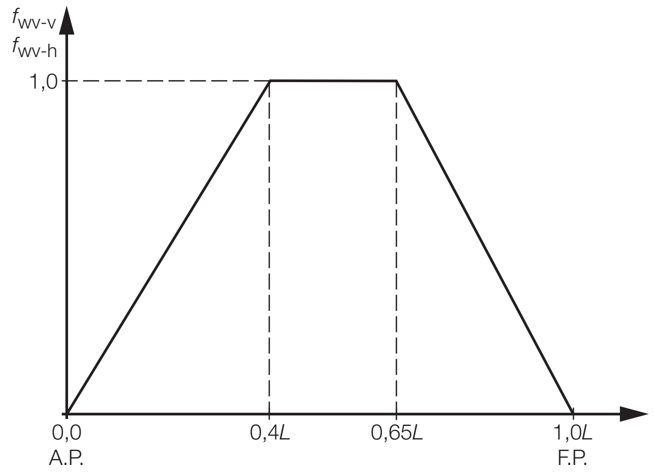


Fig. 2.3.1
Vertical and horizontal wave bending moment distribution for scantling requirements and strength assessment

3.7.2 **Vertical wave shear force**.

3.7.2.1 The envelope positive and negative vertical wave shear forces, $Q_{\text{wv-pos}}$ and $Q_{\text{wv-neg}}$, are to be taken as:

$Q_{\text{wv-pos}} = 0{,}3 f_{\text{prob}}\, f_{\text{FOI-Qwv}}\, f_{\text{qwv-pos}}\, C_{\text{wv}}\, L\, B\, (C_{\text{b}} + 0{,}7)$ kN
$Q_{\text{wv-neg}} = -0{,}3 f_{\text{prob}}\, f_{\text{FOI-Qwv}}\, f_{\text{qwv-neg}}\, C_{\text{wv}}\, L\, B\, (C_{\text{b}} + 0{,}7)$ kN

where

$f_{\text{qwv-pos}}$ = distribution factor for positive vertical wave shear force along the vessel length and is to be taken as:
= 0,0 at A.P.
$= 1{,}59\, \dfrac{C_{\text{b}}}{(C_{\text{b}} + 0{,}7)}$ for 0,2*L* to 0,3*L* from A.P.
= 0,7 for 0,4*L* to 0,6*L* from A.P.
= 1,0 for 0,7*L* to 0,85*L* from A.P.
= 0,0 at F.P.
$f_{\text{qwv-neg}}$ = distribution factor for negative vertical wave shear force along the vessel length and is to be taken as:
= 0,0 at A.P.
= 0,92 for 0,2*L* to 0,3*L* from A.P.
= 0,7 for 0,4*L* to 0,6*L* from A.P.
$= 1{,}73\, \dfrac{C_{\text{b}}}{(C_{\text{b}} + 0{,}7)}$ for 0,7*L* to 0,85*L* from A.P.
= 0,0 at F.P.
intermediate values of $f_{\text{qwv-pos}}$ and $f_{\text{qwv-neg}}$ are to be obtained by linear interpolation, *see* Fig. 2.3.3 and Fig. 2.3.4 respectively.

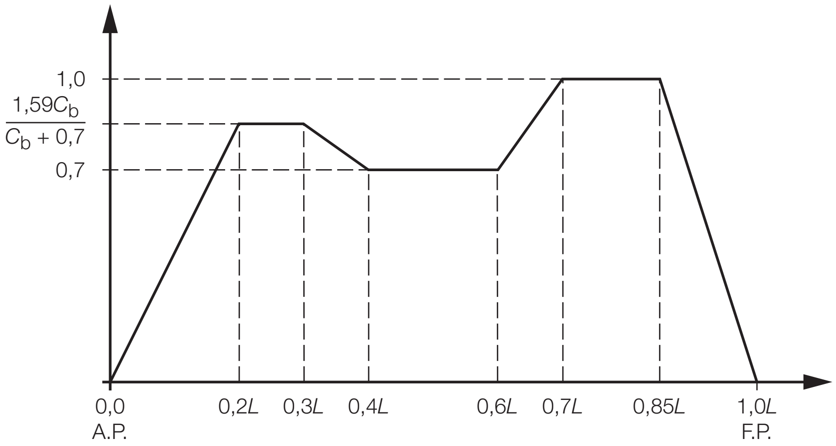


Fig. 2.3.3 Positive vertical wave shear force distribution

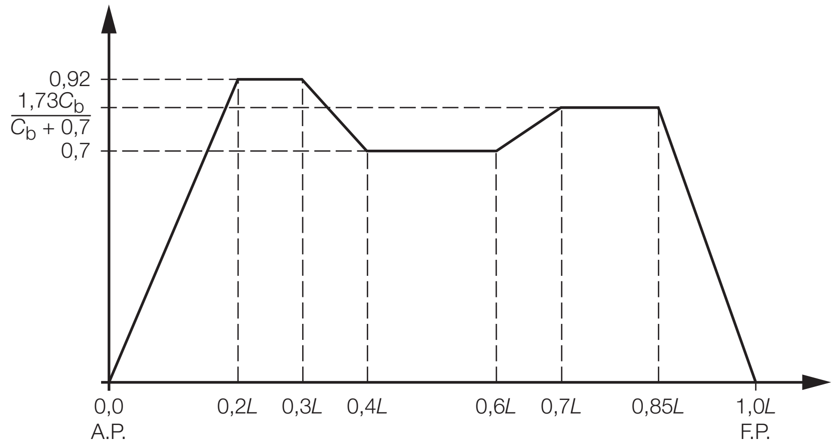


Fig. 2.3.4 Negative vertical wave shear force distribution

3.8 Dynamic local loads

3.8.1 General.

3.8.1.1 This Section provides the envelope values for dynamic wave pressure, dynamic tank pressure, green sea load and dynamic deck loads.

3.8.1.2 The envelope dynamic wave pressures are given in 3.8.2.1.

3.8.1.3 The envelope green sea load given in 3.8.3 only applies to scantling requirements and strength assessment.

3.8.1.4 The envelope dynamic tank pressure is a combination of the inertial components due to vertical, transverse and longitudinal acceleration. The envelope dynamic tank pressure components are given in 3.8.4.

3.8.1.5 The envelope dynamic deck loads are given in 3.8.5 and 3.8.6.

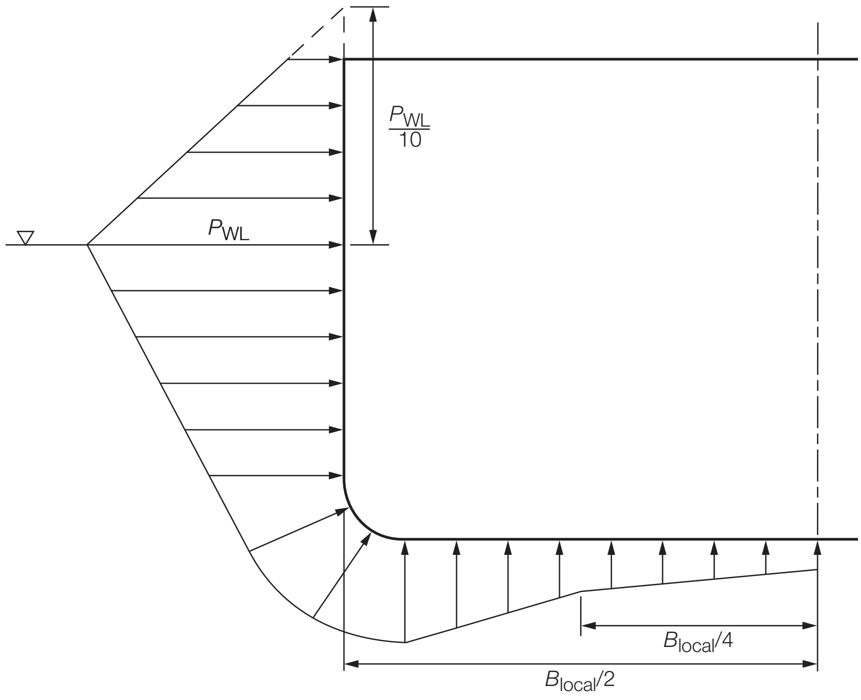


Fig. 2.3.5
Transverse distribution of maximum dynamic wave pressure for scantling requirements and strength assessment

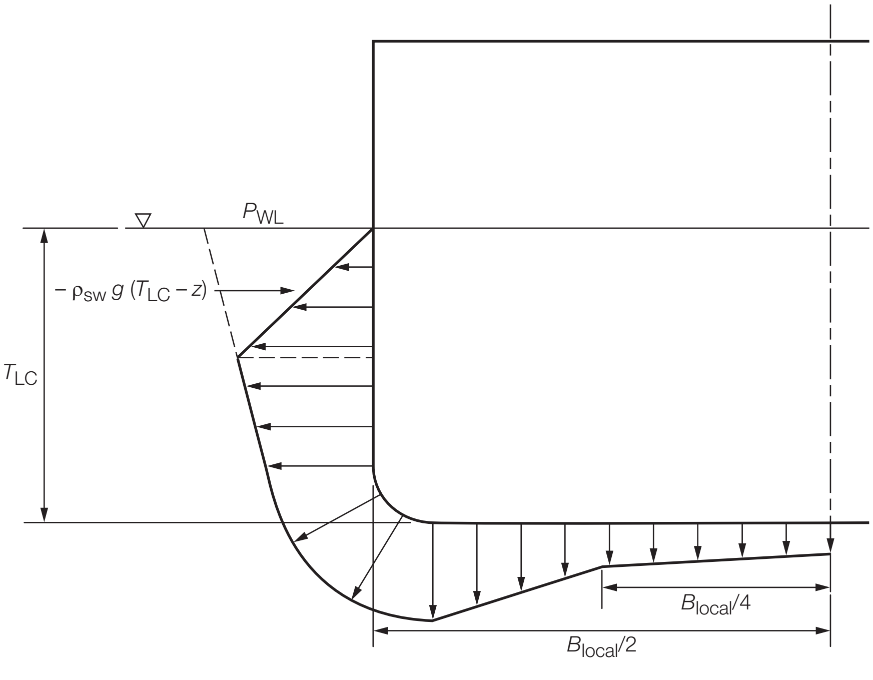


Fig. 2.3.6
Transverse distribution of minimum dynamic wave pressure for scantling requirements and strength assessment

3.8.2 **Dynamic wave pressure**.

3.8.2.1 The envelope dynamic wave pressure, $P_{ex\text{-}dyn}$, is to be taken as the greater of the following:

$$P_1 = 2f_{prob}\, f_{FOI\text{-}Pex\text{-}dyn}\, f_{nl\text{-}P1} \left[\left(P_{11} + \frac{135B_{local}}{4\,(B+75)} - 1{,}2\,(T_{LC} - z)\right) f_1 + \frac{135B_{local}}{4\,(B+75)}\, f_2\right] \quad \text{kN/m}^2$$

$$P_2 = 26f_{prob}\, f_{FOI\text{-}Pex\text{-}dyn}\, f_{nl\text{-}P2} \left[\left(\frac{B_{local}}{8}\,\theta\left(\frac{\pi}{180}\right) + f_T\, C_b\, \frac{0{,}25B_{local} + 0{,}8C_{wv}}{14}\left(0{,}7 + \frac{2z}{T_{LC}}\right)\right) f_1 + \left(\frac{B_{local}}{8}\,\theta\left(\frac{\pi}{180}\right) + f_T\, C_b\, \frac{0{,}25B_{local}}{14}\left(0{,}7 + \frac{2z}{T_{LC}}\right)\right) f_2\right] \quad \text{kN/m}^2$$

where

B_{local} = local breadth at the waterline, for considered draught, not to be taken less than 0,5B, in metres

$P_{11} = (3f_{s1} + 0{,}8)\, C_{wv}$

$f_1 = f_{lng} - f_{lng}\, f_2 + f_2$

$f_2 = 0{,}25\left(\frac{4|y|}{B_{local}} - 1\right)$ for $|y| < 0{,}25B_{local}$

$= \frac{4|y|}{B_{local}} - 1$ for $|y| \geq 0{,}25B_{local}$

$f_{s1} = C_b + \frac{1{,}33}{\sqrt{C_b}}$ at, and aft of, A.P.

$= C_b$ between 0,2L and 0,7L from A.P.

$= C_b + \frac{1{,}33}{C_b}$ at, and forward of, F.P.

intermediate values to be obtained by linear interpolation

f_{lng} = 1,0 at, and aft of, A.P.

= 0,7 for 0,2L to 0,7L from A.P.

= 1,0 at, and forward of, F.P.

intermediate values to be obtained by linear interpolation

$f_{nl\text{-}P1}$, $f_{nl\text{-}P2}$ and f_{prob} are given in 3.8.2.2 for scantling requirements and strength assessment application.

3.8.2.2 For scantling requirements and strength assessment, the envelope maximum dynamic wave pressure, $P_{ex\text{-}max}$, *see* Fig. 2.3.5, and minimum dynamic wave pressure, $P_{ex\text{-}min}$, *see* Fig. 2.3.6, are to be taken as:

$P_{ex\text{-}max} = P_{ex\text{-}dyn}$ kN/m² below still waterline

$= P_{WL} - 10\,(z - T_{LC})$ kN/m² for $T_{LC} < z \leq T_{LC} + \frac{P_{WL}}{10}$

$= 0$ kN/m² for $z > T_{LC} + \frac{P_{WL}}{10}$

$P_{ex\text{-}min} = -P_{ex\text{-}dyn}$ kN/m² below still waterline

$= 0$ kN/m² above still waterline

$P_{ex\text{-}min}$ is not to be taken as less than $-\rho_{sw}\, g\, (T_{LC} - z)$

where

$P_{ex\text{-}dyn}$ = envelope dynamic wave pressure, in kN/m², as defined in 3.8.2.1 with:

f_{prob} is defined in Table 2.3.3

$f_{nl\text{-}P1} = 1 - 0{,}2\,(f_{prob} - 0{,}5)$ but is not to be taken greater than 1,0

$f_{nl\text{-}P2} = f_\beta\,(1 - 0{,}375\,(f_{prob} - 0{,}5))$ but is not to be taken greater than 1,0

f_β = heading correction factor, *see* 6.3.1.2

P_{WL} = pressure at waterline, to be taken as $P_{ex\text{-}dyn}$ at still waterline, in kN/m².

3.8.3 **Green sea load**.

3.8.3.1 The envelope green sea load on the weather deck, P_{wdk}, is to be taken as the greater of the following:

$P_{\text{wdk}} = f_{1\text{-dk}}\,(f_{\text{op}}\,P_{1\text{-WL}} - 10z_{\text{dk-T}})$ kN/m^2
$P_{\text{wdk}} = 0{,}8f_{2\text{-dk}}\,(P_{2\text{-WL}} - 10z_{\text{dk-T}})$ kN/m^2
$P_{\text{wdk}} = 34{,}3$ kN/m^2

where

$$f_{1\text{-dk}} = 0{,}8 + \frac{L}{750}$$

$$f_{2\text{-dk}} = 0{,}5 + \frac{|\,y\,|}{B_{\text{wdk}}}$$

f_{op} = 1,0 at, and forward of, 0,2L from A.P.
= 0,8 at, and aft of, A.P.
intermediate values to be obtained by linear interpolation
$P_{1\text{-WL}}$ = P_1 pressure at still waterline for considered draught, in kN/m^2, *see* 3.8.2.1
$P_{2\text{-WL}}$ = P_2 pressure at still waterline for considered draught, in kN/m^2, *see* 3.8.2.1
$z_{\text{dk-T}}$ = distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in metres
B_{wdk} = local breadth at the weather deck, in metres

Where loads are available from a model test, they may be used for design purposes.

3.8.4 **Dynamic tank pressure**.

3.8.4.1 The envelope dynamic tank pressure, $P_{\text{in-v}}$, due to vertical tank acceleration is to be taken as:

$P_{\text{in-v}} = \rho\, a_{\text{v}}\,(z_0 - z)$ kN/m^2 for strength assessment and scantling requirements.

3.8.4.2 The envelope dynamic tank pressure, $P_{\text{in-t}}$, due to transverse acceleration is to be taken as:

$P_{\text{in-t}} = f_{\text{ull-t}}\,\rho\, a_{\text{t}}\,(y_0 - y)$ kN/m^2 for strength assessment and scantling requirements

where

$f_{\text{ull-t}}$ = factor to account for ullage in cargo tanks, and is to be taken as:
= 0,67 for cargo tanks, including cargo tanks designed for filling with water ballast
= 1,0 for ballast and other tanks.

3.8.4.3 The envelope dynamic tank pressure, $P_{\text{in-lng}}$, due to longitudinal acceleration is to be taken as:

$P_{\text{in-lng}} = f_{\text{ull-lng}}\,\rho\, a_{\text{lng}}\,(x_0 - x)$ kN/m^2 for scantling requirements and strength assessment

where

$f_{\text{ull-lng}}$ = factor to account for ullage in cargo tanks, and is to be taken as:
= 0,62 for cargo tanks, including cargo tanks designed for filling with water ballast
= 1,0 for ballast and other tanks.

3.8.4.4 For scantling requirements and strength assessment, the simultaneous acting dynamic tank pressure, $P_{\text{in-dyn}}$, is to be taken as the summation of the components for the considered dynamic load case, *see* 6.3.6.

3.8.5 **Dynamic deck pressure from distributed loading**.

3.8.5.1 The envelope dynamic deck pressure, $P_{\text{deck-dyn}}$, on decks, inner bottom and hatch covers is to be taken as:

$$P_{\text{deck-dyn}} = P_{\text{deck}}\,\frac{a_{\text{v}}}{g} \quad \text{kN/m}^2$$

where

P_{deck} = uniformly distributed pressure on lower decks and decks within superstructure, in kN/m^2, as defined in 2.3.2.1.

3.8.6 **Dynamic loads from heavy units**.

3.8.6.1 The envelope dynamic deck loads, F_{v}, F_{t}, F_{lng}, acting vertically, transversely and longitudinally on supporting structures and securing systems for heavy units of cargo, equipment or structural components are to be taken as:

$F_{\text{v}} = m_{\text{un}}\,a_{\text{v}}$ kN
$F_{\text{t}} = m_{\text{un}}\,a_{\text{t}}$ kN
$F_{\text{lng}} = m_{\text{un}}\,a_{\text{lng}}$ kN

where

m_{un} = mass of unit, in tonnes.

■ Section 4
Sloshing and impact loads

4.1 Sloshing loads

4.1.1 **Application**.

4.1.1.1 When the partial filling of tanks is contemplated in operating conditions, the sloshing loads on tank boundaries are to be assessed in accordance with the *ShipRight – FOI procedure*. Full account is to be taken of the operating requirements on station with regard to the filling, transfer and export operations for oil bulk storage tanks.

4.2 Bottom slamming loads

4.2.1 **Application and limitations**.

4.2.1.1 The slamming loads in this Section apply to units with $C_b \geq 0{,}7$ and bottom slamming draught $\geq 0{,}01L$ and $\leq 0{,}045L$. For operation at deeper draughts, the slamming loads will need to be specially considered.

4.2.1.2 For units with unconventional bow shapes or for harsh service, the slamming loads, green sea loads and bow impact loads are to be determined by a site-specific analysis. The analysis results are to be verified by model tests.

4.2.2 **Slamming pressure**.

4.2.2.1 The bottom slamming pressure, P_{slm}, is to be taken as the greater of:

$$P_{slm\text{-}mt} = f_{slm}\, f_{FOI\text{-}Pex\text{-}dyn}\, 130g\, c_{slm\text{-}mt}\, e^{c_1} \quad \text{kN/m}^2 \text{ for empty tanks}$$

$$P_{slm\text{-}full} = f_{slm}\, f_{FOI\text{-}Pex\text{-}dyn}\, 130g\, c_{slm\text{-}full}\, e^{c_1} - c_{av}\, \rho\, g\, z_{ball} \quad \text{kN/m}^2 \text{ for full tanks}$$

where

g = acceleration due to gravity, 9,81 m/s^2
f_{slm} = longitudinal slamming distribution factor, *see* Fig. 2.4.1
= 0,0 at 0,5L
= 1,0 at $[0{,}175 - 0{,}5\,(C_{bl} - 0{,}7)]\,L$ from F.P.
= 1,0 at $[0{,}1 - 0{,}5\,(C_{bl} - 0{,}7)]\,L$ from F.P.
= 0,5 at, and forward of, F.P.
intermediate values to be obtained by linear interpolation
$f_{FOI\text{-}Pex\text{-}dyn}$ = environmental FOI factor due to dynamic wave pressure. For the initial design of units to be taken as that derived for the light load draught in Table 2.3.2
C_{bl} = block coefficient, C_b, as defined in 3.1, but not to be taken less than 0,7 or greater than 0,8
= slamming coefficient for empty tanks
$c_{slm\text{-}mt} = 5{,}95 - 10{,}5 \left(\dfrac{T_{FP\text{-}mt}}{L}\right)^{0{,}2}$
= slamming coefficient for full tanks
$c_{slm\text{-}full} = 5{,}95 - 10{,}5 \left(\dfrac{T_{FP\text{-}full}}{L}\right)^{0{,}2}$
c_1 = 0,0 for $L \leq 180$ m
= $-0{,}0125\,(L - 180)^{0{,}705}$ for $L > 180$ m
$T_{FP\text{-}mt}$ = design slamming light load draught at F.P. with tanks within the bottom slamming region empty, as defined in 4.2.2.3, in metres
$T_{FP\text{-}full}$ = design slamming light load draught at F.P. with tanks within the bottom slamming region full, as defined in 4.2.2.4, in metres
c_{av} = dynamic load coefficient, to be taken as 1,25
L = Rule length, in metres
z_{ball} = vertical distance from tank top to load point, in metres.

4.2.2.2 The designer is to provide the design slamming draughts $T_{FP\text{-}mt}$ and $T_{FP\text{-}full}$.

4.2.2.3 The design slamming draught at the F.P., $T_{FP\text{-}mt}$, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for all sea-going conditions wherein the tanks within the bottom slamming region are empty.

4.2.2.4 The design slamming draught at the F.P., $T_{FP\text{-}full}$, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for any sea-going conditions wherein the tanks within the bottom slamming region are full.

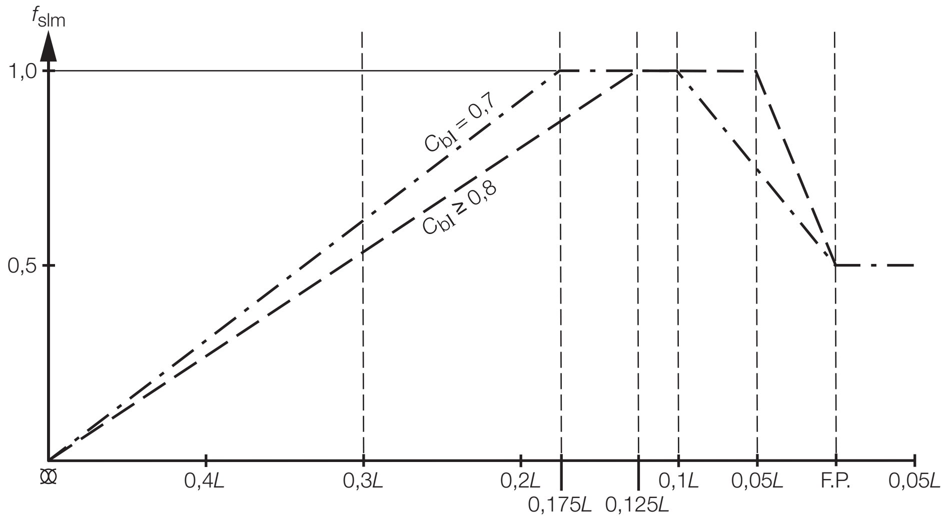


Fig. 2.4.1 Longitudinal distribution of slamming pressure

4.2.2.5 The loading guidance information is to indicate clearly the design slamming draught.

4.3 Bow impact loads

4.3.1 Application and limitations.

4.3.1.1 The bow impact pressure applies to the side structure in the area forward of 0,1*L* aft of F.P. and between the waterline at draught T_{LT} and the highest deck at side.

4.3.2 Bow impact pressure.

4.3.2.1 The bow impact pressure, P_{im}, is to be taken as:

$$P_{im} = 1{,}025 f_{im}\, f_{FOI\text{-}Pex\text{-}dyn}\, c_{im}\, V_{im}^2 \sin\gamma_{wl} \quad \text{kN/m}^2$$

where

f_{im} = 0,55 at 0,1*L* aft of F.P.
= 0,9 at 0,0125*L* aft of F.P.
= 1,0 at, and forward of, F.P.
intermediate values to be obtained by linear interpolation

$f_{FOI\text{-}Pex\text{-}dyn}$ = environmental FOI factor due to dynamic wave pressure
For the initial design of units to be taken as:
$f_{FOI\text{-}Pex\text{-}dyn}$ for the T_{LT} in Table 2.3.2 for the pressure calculation at the light load waterline
$f_{FOI\text{-}Pex\text{-}dyn}$ for the T_{sc} in Table 2.3.2 for the pressure calculation at and above the deep load waterline
For the pressure calculation in between T_{LT} and T_{sc}, the factor is be obtained by interpolating between the $f_{FOI\text{-}Pex\text{-}dyn}$ factors for T_{LT} and for T_{sc}

V_{im} = impact speed, in m/s
For fixed locations, impact speed to be taken as $5 \sin\alpha_{wl} + \sqrt{L}$

α_{wl} = local waterline angle at the position considered, but is not to be taken as less than 35°, *see* Fig. 2.4.2

γ_{wl} = local bow impact angle measured normal to the shell from the horizontal to the tangent line at the position considered, but is not to be less than 50°, *see* Fig. 2.4.2

c_{im} = 1,0 for positions between draughts T_{LT} and T_{sc}

$$= \sqrt{1 + \cos^2\left[\frac{90\,(h_{fb} - 2h_o)}{h_{fb}}\right]} \quad \text{for positions above draught } T_{sc}$$

h_{fb} = vertical distance from the waterline at draught T_{sc} to the highest deck at side, *see* Fig. 2.4.2, in metres

h_o = vertical distance from the waterline at draught T_{sc} to the position considered, *see* Fig. 2.4.2, in metres

L = Rule length, in metres

T_{sc} = scantling draught, in metres

T_{LT} = minimum design light draught, in metres

W_{Lj} = waterline at the position considered, *see* Fig. 2.4.2

NOTE
Where local bow impact angle measured normal to the shell, γ_{wl}, is not available, this angle may be taken as:

$$\gamma_{wl} = \tan^{-1}\left(\frac{\tan\beta_{pl}}{\cos\alpha_{wl}}\right)$$

where

β_{pl} = local body plan angle at the position considered from the horizontal to the tangent line, but is not to be less than 35°.

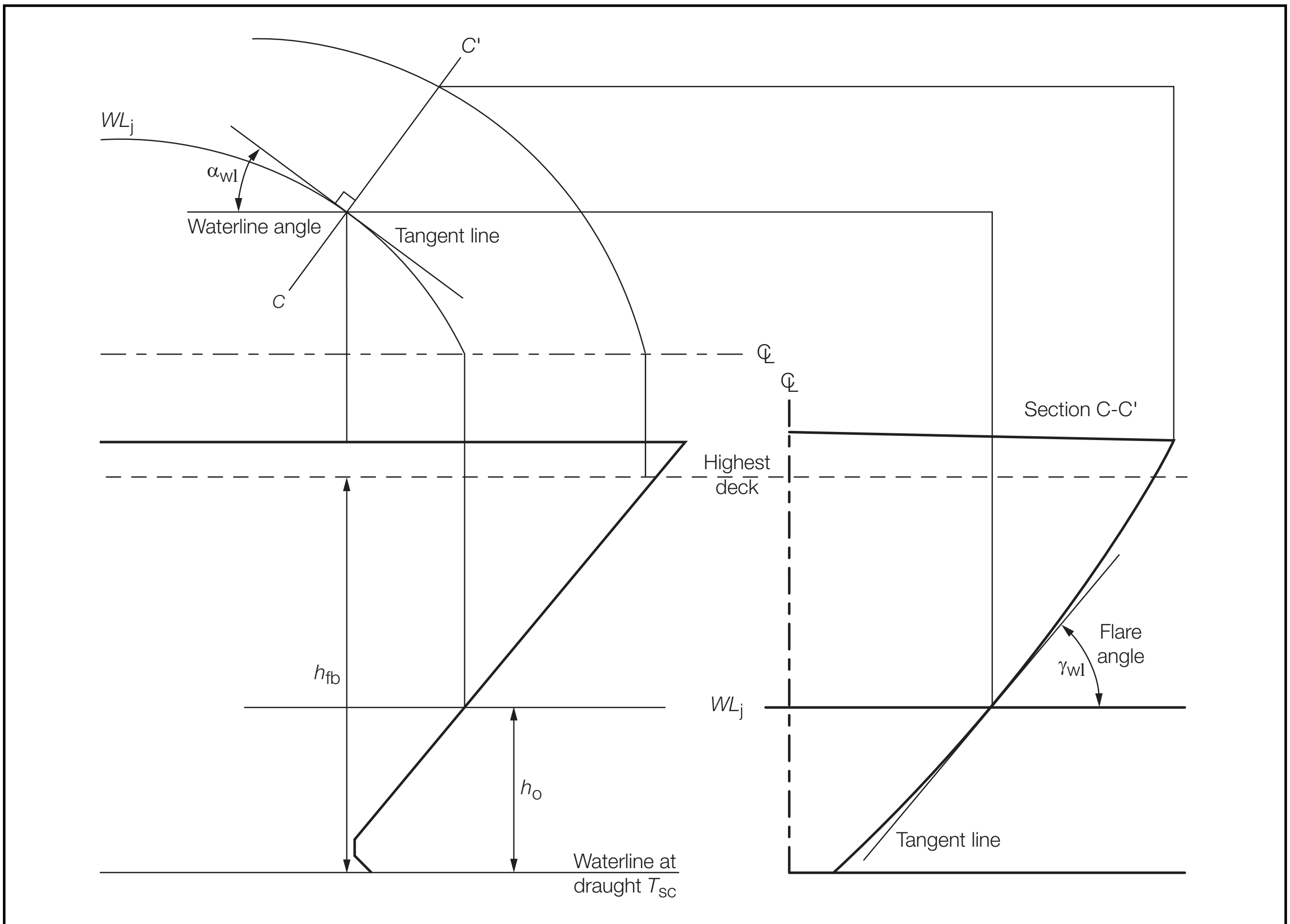


Fig. 2.4.2 Definition of bow geometry

Section 5
Accidental loads

5.1 Flooded condition

5.1.1 **Global loads**.

5.1.1.1 The still water bending moments and the still water shear forces in flooded condition are to be determined for each flooding scenario, considering the damaged compartments flooded up to the equilibrium waterline.

5.1.2 **Local pressure**.

5.1.2.1 The pressure in compartments and tanks in flooded condition or damaged condition is to be taken as $P_{\text{in-flood}}$, *see* 2.3.2.1.

5.1.3 **Assessment**.

5.1.3.1 Flooding strength calculations are to be carried out to determine the effects of accidental flooding on the hull strength. Flooding calculations are to be undertaken for all flooding scenarios required by National Regulations. When considering the static and dynamic loads acting simultaneously (S+D), credit may be given to agreed documented mitigation measures where permitted by the National Regulations.

5.2 Blast condition

5.2.1 **Global loads**.

5.2.1.1 The still water bending moments are to be determined for the blast accident scenario, considering all loading conditions where there is a risk of blast loads.

5.2.2 **Pressure**.

5.2.2.1 Generally, the blast pressure is a rapidly propagating pressure or shock-wave in the atmosphere, with high pressure, high density and high particle velocity.

5.2.2.2 The design blast pressures are to be defined by the Owners/designers and are to comply with National Regulations.

5.2.2.3 Design calculations are to be submitted which may be based on elastic analysis or elastoplastic design methods.

5.2.3 **Assessment**.

5.2.3.1 Assessment of the potential fire loadings and blast pressures are to be based on the specific hazards associated with the general layout of the unit, production and process activities and operational constraints. For assessment of the post accident condition, the static loads may be reduced if damage control or recovery measures are implemented, *see* Pt 4, Ch 3,4.3.1.

5.2.3.2 The blast load case is applicable primarily to the upper deck, deck-house and turret boundary. The pressures acting on the opposite side of these structures to the blast load (ballast water pressure, inert gas pressure, etc.) may be ignored when assessing the local scantlings but the hull girder stresses (due to shear and bending) are to be included. The amount of damage to the structure following a blast is to be considered in the assessment.

5.2.4 **Boundary bulkheads and main decks**.

5.2.4.1 Particular consideration is to be given to the potential effects of fire and blast impinging on exposed boundary bulkheads of accommodation spaces and main decks. Where boundary bulkheads and main decks can be subjected to blast loading, the scantlings are to comply with Pt 4, Ch 3,4.16.9.

5.3 Collision loads

5.3.1 **General**.

5.3.1.1 Collision loads are to be considered in the design of the unit as applicable to the function of the unit. In general, the loads described in Pt 4, Ch 3 are to be considered.

Section 6
Combination of loads

6.1 Symbols

$M_{v\text{-}total}$ = design vertical bending moment, in kNm
$M_{sw\text{-}perm\text{-}maint}$ = permissible hull girder hogging and sagging still water bending moment envelopes for inspection/maintenance condition, in kNm, *see* 2.1 and Table 2.6.1
$M_{sw\text{-}perm\text{-}sea}$ = permissible hull girder hogging and sagging still water bending moment envelopes for transit condition, in kNm, *see* 2.1 and Table 2.6.1
$M_{sw\text{-}perm\text{-}oper}$ = permissible hull girder hogging and sagging still water bending moment envelopes for operational condition, in kNm, *see* 2.1 and Table 2.6.1
$M_{sw\text{-}perm\text{-}flood}$ = permissible hull girder hogging and sagging still water bending moment envelopes for flooded condition, in kNm, *see* Table 2.6.1
M_{wv} = vertical wave bending moment for a considered dynamic load case, in kNm, *see* 6.3.2.1
$M_{h\text{-}total}$ = design horizontal bending moment, in kNm
M_{h} = horizontal wave bending moment for a considered dynamic load case, in kNm, *see* 6.3.2.1
$M_{wv\text{-}hog}$ = hogging vertical wave bending moment, in kNm, *see* 3.7.1.1
$M_{wv\text{-}sag}$ = sagging vertical wave bending moment, in kNm, *see* 3.7.1.1
$M_{wv\text{-}h}$ = horizontal wave bending moment, in kNm, *see* 3.7.1.1
Q = design vertical shear force, in kN
$Q_{sw\text{-}perm\text{-}maint}$ = permissible hull girder positive and negative still water shear force limits for inspection/maintenance condition, in kN, *see* 2.1 and Table 2.6.1
$Q_{sw\text{-}perm\text{-}sea}$ = permissible hull girder positive and negative still water shear force limits for transit condition, in kN, *see* 2.1 and Table 2.6.1
$Q_{sw\text{-}perm\text{-}oper}$ = permissible hull girder positive and negative still water shear force limits for operational condition, in kN, *see* 2.1 and Table 2.6.1
$Q_{sw\text{-}perm\text{-}flood}$ = permissible hull girder positive and negative still water shear force envelopes for flood condition, in kN, *see* Table 2.6.1
Q_{wv} = vertical wave shear force for a considered dynamic load case, in kN, *see* 6.3.2.1
$Q_{wv\text{-}pos}$ = envelope positive vertical wave shear force, in kN, as defined in 3.7.2.1
$Q_{wv\text{-}neg}$ = envelope negative vertical wave shear force, in kN, as defined in 3.7.2.1
f_{mv} = dynamic load combination factor for vertical wave bending moment for considered dynamic load case, as defined in 6.3.2.1
f_{qv} = dynamic load combination factor for vertical wave shear force for considered dynamic load case, as defined in 6.3.3.1
f_{β} = heading correction factor, as defined in 6.3.1.2
P_{ex} = design sea pressure, in kN/m^2
P_{hys} = static sea pressure at considered draught, in kN/m^2, as defined in 2.3.2.1
$P_{wv\text{-}dyn}$ = dynamic wave pressure for a considered dynamic load case, in kN/m^2, as defined in 6.3.4.1
$P_{wdk\text{-}dyn}$ = green sea load for a considered dynamic load case, in kN/m^2, as defined in 6.3.5.1
P_{in} = design tank pressure, in kN/m^2
$P_{in\text{-}test}$ = tank testing pressure, in kN/m^2, as defined in Table 2.2.1
$P_{in\text{-}air}$ = static tank pressure in the case of overfilling, in kN/m^2, as defined in Table 2.2.1
P_{drop} = added overpressure due to liquid flow through air pipe or overflow pipe, in kN/m^2, as defined in Table 2.2.1 and Table 2.6.1
P_{valve} = setting of pressure relief valve, in kN/m^2, as defined in Table 2.2.1
$P_{in\text{-}tk}$ = static tank pressure, in kN/m^2, as defined in Table 2.2.1
$P_{in\text{-}dyn}$ = dynamic tank pressure for a considered dynamic load case, in kN/m^2, as defined in 6.3.6.1
$P_{in\text{-}flood}$ = pressure in compartments and tanks in flooded or damaged condition, in kN/m^2, as defined in Table 2.2.1
P_{stat} = static pressure on decks and inner bottom, in kN/m^2, as defined in Table 2.2.1
P_{dk} = design deck pressure, in kN/m^2, as defined in Table 2.2.1
$P_{deck\text{-}dyn}$ = envelope dynamic deck pressure on decks, inner bottom and hatch cover, in kN/m^2, as defined in 3.8.5.1
$P_{dk\text{-}dyn}$ = dynamic deck pressure on decks, inner bottom and hatch covers for a considered dynamic load case, in kN/m^2, as defined in 6.3.7.1
P_{ctr} = dynamic wave pressure at bottom centreline, as defined in 6.3.7.1
= $f_{ctr}\, P_{ex\text{-}max}$ kN/m^2
P_{bilge} = dynamic wave pressure at $z = 0$ and $y = B_{local}/2$, as defined in 6.3.7.1
= $f_{bilge}\, P_{ex\text{-}max}$ kN/m^2
P_{WL} = dynamic wave pressure at waterline, as defined in 6.3.7.1
= $f_{WL}\, P_{ex\text{-}max}$ kN/m^2
$P_{ex\text{-}max}$ = envelope maximum dynamic wave pressure, in kN/m^2, as defined in 6.3.4.1
$P_{1\text{-}WL}$ = P_1 pressure at still waterline for considered draught, in kN/m^2, *see* 6.3.4.1
$P_{2\text{-}WL}$ = P_2 pressure at still waterline for considered draught, in kN/m^2, *see* 6.3.4.1

F_{stat} = load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN, as defined in 2.3.2.1
$F_{dk\text{-}dyn}$ = dynamic load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN, as defined in 6.3.7.2
F_v = envelope vertical dynamic load from heavy units, in kN, *see* 3.8.6
f_{WL} = dynamic load combination factor for dynamic wave pressure, P_{WL}, at still waterline for considered dynamic load case, *see* 6.3.4.1
f_{bilge} = dynamic load combination factor for dynamic wave pressure, P_{bilge}, at bilge for considered dynamic load case, *see* 6.3.4.1
f_{ctr} = dynamic load combination factor for dynamic wave pressure, P_{ctr}, at centreline for considered dynamic load case, *see* 6.3.4.1
$f_{1\text{-}dk} = 0{,}8 + \dfrac{L}{750}$ *see* 6.3.5.1
$f_{2\text{-}dk} = 0{,}5 + \dfrac{|y|}{B_{wdk}}$ *see* 6.3.5.1
f_{op} = 1,0 at and forward of 0,2L from A.P.
= 0,8 at and aft of A.P.
intermediate values to be obtained by linear interpolation, *see* 6.3.5.1
f_v = dynamic load combination factor for vertical acceleration for considered dynamic load case. f_v is to be taken as appropriate to the tank location, *see* 6.3.6.1
$f_{v\text{-}mid}$ = dynamic load combination factor for vertical acceleration for considered dynamic load case, *see* 6.3.6.1
f_t = dynamic load combination factor for transverse acceleration for considered dynamic load case, *see* 6.3.6.1
f_{lng} = dynamic load combination factor for longitudinal acceleration for considered dynamic load case. f_{lng} is to be taken as most appropriate dependent on tank location, *see* 6.3.6.1
$z_{dk\text{-}T}$ = distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in metres, *see* 6.3.5.1
L = Rule length, in metres
B_{wdk} = local breadth at the weather deck, in metres, *see* 6.3.4.1
B_{local} = local breadth at waterline for considered draught, in metres, *see* 6.3.4.1
T_{LC} = draught in the loading condition being considered, in metres, *see* 6.3.4.1
x = longitudinal coordinate, in metres
y = transverse coordinate, in metres
z = vertical coordinate, in metres
x_0 = longitudinal coordinate of reference point, in metres
y_0 = transverse coordinate of reference point, in metres
z_0 = vertical coordinate of reference point, in metres
ρ_{sw} = density of sea-water, 1,025 tonnes/m^3
g = acceleration due to gravity, 9,81m/s^2.

6.2 General

6.2.1 Application.

6.2.1.1 The design load combinations given in Table 2.6.1 corresponding to the applicable static load scenarios given in 2.3 are to be used as the basis for the scantling requirements and strength assessment (by FEM).

6.2.1.2 For each dynamic load case, the envelope load values as given in Section 3 are multiplied with dynamic load combination factors to give simultaneously acting dynamic loads.

6.2.1.3 The procedures for calculating the simultaneously acting dynamic loads are given in 6.3. The dynamic loads for the transit/disconnected condition are given in Section 7. The dynamic loads for the site-specific load scenarios are given in Section 8.

Table 2.6.1 Design load combinations

Global hull girder loads										
Load component			Operation on-site		Inspection/maintenance		Transit/Disconnected		Flooded	
			S	S+D	S	S+D	S	S+D	S	S+D
$M_{\text{v-total}}$			$M_{\text{sw-perm-oper}}$	$M_{\text{sw-perm-oper}} + M_{\text{wv}}$	$M_{\text{sw-perm-maint}}$	$M_{\text{sw-perm-maint}} + M_{\text{wv}}$	$M_{\text{sw-perm-sea}}$	$M_{\text{sw-perm-sea}} + M_{\text{wv}}$	$M_{\text{sw-perm-flood}}$	$M_{\text{sw-perm-flood}} + M_{\text{wv}}$
$M_{\text{h-total}}$			–	M_{h}	–	M_{h}	–	M_{h}	–	M_{h}
Q			$Q_{\text{sw-perm-oper}}$	$Q_{\text{sw-perm-oper}} + Q_{\text{wv}}$	$Q_{\text{sw-perm-maint}}$	$Q_{\text{sw-perm-maint}} + Q_{\text{wv}}$	$Q_{\text{sw-perm-sea}}$	$Q_{\text{sw-perm-sea}} + Q_{\text{wv}}$	$Q_{\text{sw-perm-flood}}$	$Q_{\text{sw-perm-flood}} + Qwv$
Local loads										
Load component		Space type	Operation on-site		Inspection/maintenance		Transit/Disconnected		Flooded	
			S	S+D	S	S+D	S	S+D	S	S+D
External sea pressure	P_{ex}	Exposed deck		$P_{\text{wdk\_dyn}}$		$P_{\text{wdk-dyn}}$		$P_{\text{wdk-dyn}}$		$\max(P_{\text{hys}} + P_{\text{ex-dyn}}, P_{\text{wdk-dyn}})$
		Hull envelope	P_{hys}	$P_{\text{hys}} + P_{\text{wv-dyn}}$	P_{hys}	$P_{\text{hys}} + P_{\text{wv-dyn}}$	P_{hys}	$P_{\text{hys}} + P_{\text{wv-dyn}}$	P_{hys}	$P_{\text{hys}} + P_{\text{wv-dyn}}$
Liquid pressure	P_{in}	Ballast tanks	$P_{\text{in-air}} + P_{\text{drop}}$	$P_{\text{in-tk}} + P_{\text{in-dyn}}$	$P_{\text{in-test}}$	$P_{\text{in-test}} + P_{\text{in-dyn}}$	$P_{\text{in-air}} + P_{\text{drop}}$	$P_{\text{in-tk}} + P_{\text{in-dyn}}$	$P_{\text{in-flood}}$	$\max(P_{\text{in-tk}}, P_{\text{in-flood}}) + P_{\text{in-dyn}}$
		Cargo tanks/ other tanks designed for liquid filling	$P_{\text{in-tk}} + P_{\text{valve}}$	$P_{\text{in-tk}} + P_{\text{in-dyn}}$	$\max(P_{\text{in-tk}} + P_{\text{valve}}, P_{\text{in-test}})$	$P_{\text{in-test}} + P_{\text{in-dyn}}$	$P_{\text{in-tk}} + P_{\text{valve}}$	$P_{\text{in-tk}} + P_{\text{in-dyn}}$	$P_{\text{in-flood}}$	$\max(P_{\text{in-tk}}, P_{\text{in-flood}}) + P_{\text{in-dyn}}$
		Fresh water and fuel/lube oil tanks	$P_{\text{in-air}}$	$P_{\text{in-tk}} + P_{\text{in-dyn}}$	$P_{\text{in-test}}$	$P_{\text{in-test}} + P_{\text{in-dyn}}$	$P_{\text{in-air}}$	$P_{\text{in-tk}} + P_{\text{in-dyn}}$	$P_{\text{in-flood}}$	$\max(P_{\text{in-tk}}, P_{\text{in-flood}}) + P_{\text{in-dyn}}$
		Water tight boundaries/ void spaces			$P_{\text{in-test}}$	$P_{\text{in-test}} + P_{\text{in-dyn}}$			$P_{\text{in-flood}}$	$\max(P_{\text{in-tk}}, P_{\text{in-flood}}) + P_{\text{in-dyn}}$
		Dry space							$P_{\text{in-flood}}$	$P_{\text{in-flood}} + P_{\text{in-dyn}}$
Deck loads	P_{dk}	Dry space	P_{stat}	$P_{\text{stat}} + P_{\text{dk-dyn}}$	P_{stat}	$P_{\text{stat}} + P_{\text{dk-dyn}}$	P_{stat}	$P_{\text{stat}} + P_{\text{dk-dyn}}$	P_{stat}	$P_{\text{stat}} + P_{\text{dk-dyn}}$

NOTE
All the dynamic wave loads are to be adjusted by the f_{prob} factor. The value of f_{prob} is dependent on the operational condition, *see* Table 2.3.3.

6.3 Application of dynamic loads

6.3.1 Dynamic load combination factors.

6.3.1.1 For strength assessment by FEM, the dynamic load combination factors used for the calculations of the simultaneously acting dynamic loads are to be taken as given in:

- Table 2.7.2 for transit/disconnected condition, *see* 7.1;
- Table 2.8.2 for site-specific load scenarios, *see* 8.3.1.2.

For scantling assessment, the dynamic load factors are to be taken as given in:

- Table 2.7.1 for scantling assessment, *see* 7.2;
- Table 2.8.1 for scantling assessment, *see* 8.3.

6.3.1.2 The heading correction factor, f_β, is to be taken as follows:

- For 'Transit under tow' and 'Transit or Sea-going' operational conditions using the world wide environment, as defined in Table 2.3.3:
  f_β = 0,8 for beam sea dynamic load cases
  = 1,0 for all other dynamic load cases
- For all other operational conditions, as defined in Table 2.3.3:
  f_β = 1,0 for beam sea dynamic load cases.

6.3.2 Vertical and Horizontal wave bending moment for a considered dynamic load case.

6.3.2.1 The simultaneously acting vertical wave bending moment, M_{wv} and horizontal wave bending moment, M_h, are to be taken as:

- Vertical wave bending moment:
  $M_{wv} = f_\beta f_{mv} M_{wv\text{-}hog}$ kNm for $f_{mv} \geq 0$
  $M_{wv} = -f_\beta f_{mv} M_{wv\text{-}sag}$ kNm for $f_{mv} < 0$
- Horizontal wave bending moment:
  $M_h = f_\beta f_{mh} M_{wv\text{-}h}$ kNm.

6.3.3 Vertical wave shear force for a considered dynamic load case.

6.3.3.1 The simultaneously acting vertical wave shear force, Q_{wv}, is to be taken as:

$Q_{wv} = f_\beta f_{qv} Q_{wv\text{-}pos}$ kNm for $f_{qv} \geq 0$
$Q_{wv} = -f_\beta f_{qv} Q_{wv\text{-}neg}$ kNm for $f_{qv} < 0$.

6.3.4 Dynamic wave pressure distribution for a considered dynamic load case.

6.3.4.1 The simultaneously acting dynamic wave pressure, $P_{wv\text{-}dyn}$, is to be taken as follows, but not to be less than $-\rho_{sw}\, g\, (T_{LC} - z)$ below still waterline or less than 0 above still waterline:

- For the port and starboard side within the cargo tank region:

$$P_{wv\text{-}dyn} = P_{ctr} + \frac{|y|}{0{,}5B_{local}} (P_{bilge} - P_{ctr}) \quad \text{between centreline and start of bilge}$$

$$P_{wv\text{-}dyn} = P_{bilge} + \frac{z}{T_{LC}} (P_{WL} - P_{bilge}) \quad \text{between end of bilge and still waterline}$$

$$P_{wv\text{-}dyn} = P_{WL} - 10\,(z - T_{LC}) \quad \text{for side shell above still waterline}$$

intermediate values of $P_{wv\text{-}dyn}$ around the bilge are to be obtained by linear interpolation along the vertical distance.

- For the port and starboard side outside the cargo tank region:

$$P_{wv\text{-}dyn} = P_{ctr} + \frac{z}{T_{LC}} (P_{WL} - P_{ctr}) \quad \text{between bottom centreline and still waterline}$$

$$P_{wv\text{-}dyn} = P_{WL} - 10\,(z - T_{LC}) \quad \text{above still waterline}$$

where

P_{ctr} = dynamic wave pressure at bottom centreline, to be taken as:
= $f_{ctr} P_{ex\text{-}max}$ kN/m^2
P_{bilge} = dynamic wave pressure at $z = 0$ and $y = B_{local}/2$, to be taken as:
= $f_{bilge} P_{ex\text{-}max}$ kN/m^2
P_{WL} = dynamic wave pressure at waterline, to be taken as:
= $f_{WL} P_{ex\text{-}max}$ kN/m^2.

6.3.4.2 Fig. 2.6.1 to Fig. 2.6.3 illustrate simultaneously acting dynamic wave pressures.

6.3.5 **Green sea load of a considered dynamic load case**.

6.3.5.1 The simultaneously acting green sea load on the weather deck, $P_{wdk\text{-}dyn}$:

Table 2.6.2 Green sea load

Inclined green sea load, *see* Note
$P_{wdk\text{-}dyn} = \max. (f_{1\text{-}dk} (f_{WL} f_{op} P_{1\text{–}WL} - 10 z_{dk\text{-}T}), 0{,}8 (f_{WL} P_{2\text{-}WL} - 10 z_{dk\text{-}T}), 34{,}3)$ kN/m^2
Uniformly distributed
$P_{wdk\text{-}dyn} = \max. (f_{1\text{-}dk} (f_{WL} f_{op} P_{1\text{–}WL} - 10 z_{dk\text{-}T}), 0{,}8 (f_{WL} P_{2\text{-}WL} - 10 z_{dk\text{-}T}), 34{,}3)$ kN/m^2
NOTE Inclined green sea load is obtained by linear interpolation between port side and starboard side, with load decreasing from port side to starboard side, with the maximum value at vessel side given by the formula and the minimum value at the opposite side taken as 34,3 kN/m^2. The assessment is then to be repeated, with loading decreasing from starboard side to port side.

6.3.6 **Dynamic tank pressure for a considered dynamic load case**.

6.3.6.1 The simultaneously acting dynamic tank pressure, $P_{in\text{-}dyn}$, is to be taken as:

- For tanks in the cargo region:

$$P_{in\text{-}dyn} = f_\beta (f_v P_{in\text{-}v} + f_t P_{in\text{-}t} + f_{lng} P_{in\text{-}lng}) \text{ kN/m}^2$$

- For tanks outside the cargo region:

$$P_{in\text{-}dyn} = f_\beta (f_{v\text{-}mid} P_{in\text{-}v} + \left| f_t P_{in\text{-}t} \right| + \left| f_{lng} P_{in\text{-}lng} \right|) \text{ kN/m}^2$$

where

$P_{in\text{-}v}$ = envelope dynamic tank pressure due to vertical acceleration, as defined in 3.8.4.1 with reference point z_0 taken as:
(a) top of tank
(b) top of air pipe/overflow for ballast tanks designed
see Fig. 2.6.4, in kN/m^2

$P_{in\text{-}t}$ = envelope dynamic tank pressure due to transverse acceleration, as defined in 3.8.4.2 with reference point y_0 taken as:
(a) tank top towards port side for $f_t > 0$
(b) tank top towards starboard side for $f_t < 0$
see Fig. 2.6.5, in kN/m^2

$P_{in\text{-}lng}$ = envelope dynamic tank pressure due to longitudinal acceleration, as defined in 3.8.4.3 with reference point x_0 taken as:
(a) forward bulkhead for $f_{lng} > 0$
(b) aft bulkhead of the tank for $f_{lng} < 0$.
see Fig. 2.6.6, in kN/m^2

NOTES

1. For a non-parallel tank, y_0 should be selected from either forward or aft bulkhead corresponding to the reference point x_0. If the longitudinal load combination factor $f_{lng} = 0$, y_0 should be selected from the bulkhead with the greater breadth.
2. The vertical, transverse and longitudinal acceleration is to be taken at the centre of gravity of the tank under consideration.

6.3.7 **Dynamic deck loads for a considered dynamic load case**.

6.3.7.1 The simultaneously acting dynamic deck load for uniformly distributed load, $P_{dk\text{-}dyn}$, on the enclosed upper deck, where a forecastle or poop is fitted, and also on all lower decks, is to be taken as:

$$P_{dk\text{-}dyn} = f_\beta f_{v\text{-}mid} P_{deck\text{-}dyn} \text{ kN/m}^2$$

6.3.7.2 The simultaneously acting dynamic vertical force for heavy units, $F_{dk\text{-}dyn}$, acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, is to be taken as:

$$F_{dk\text{-}dyn} = f_\beta f_{v\text{-}mid} F_v \text{ kN.}$$

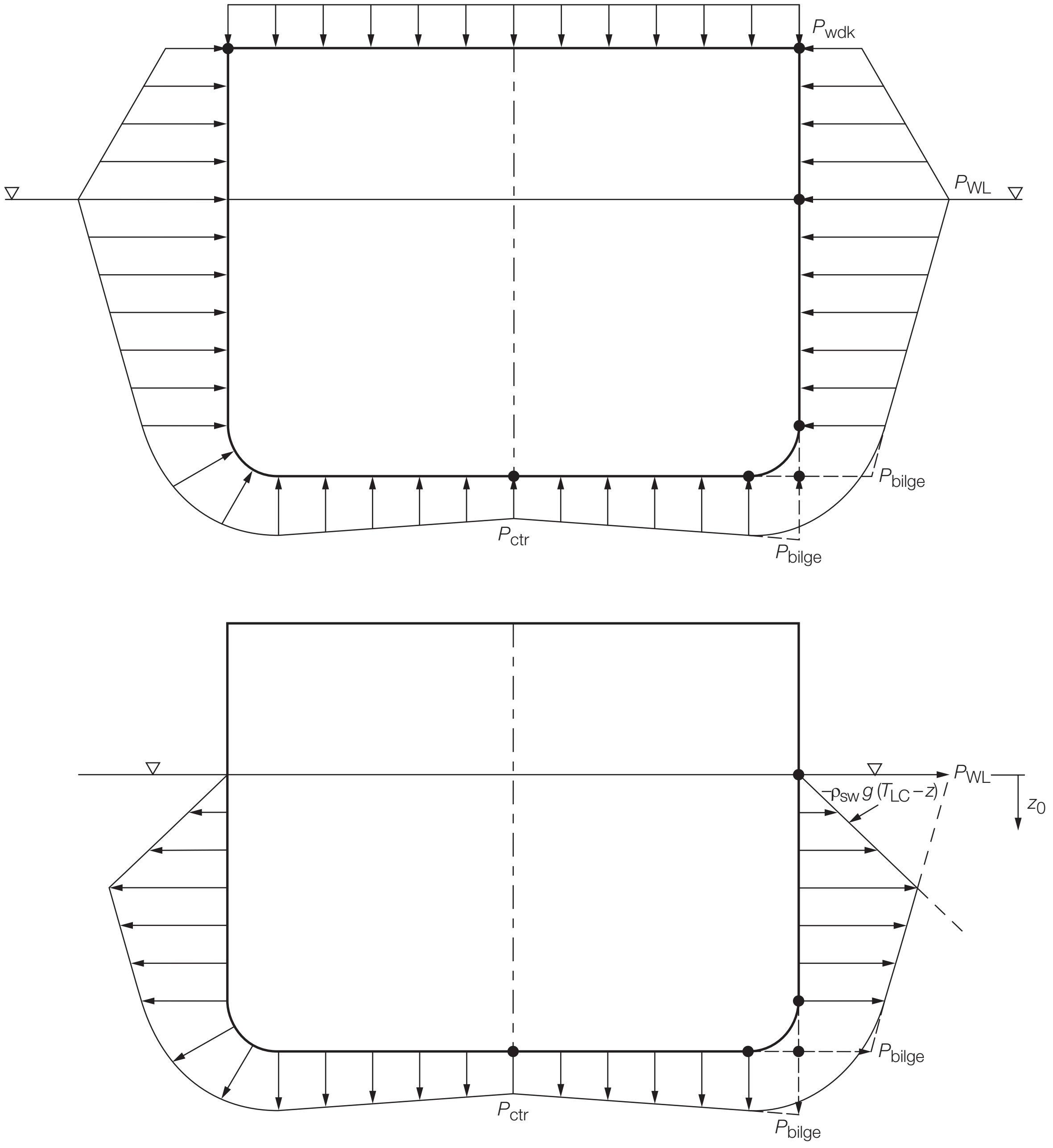


Fig. 2.6.1 Dynamic wave pressure for head sea dynamic load cases

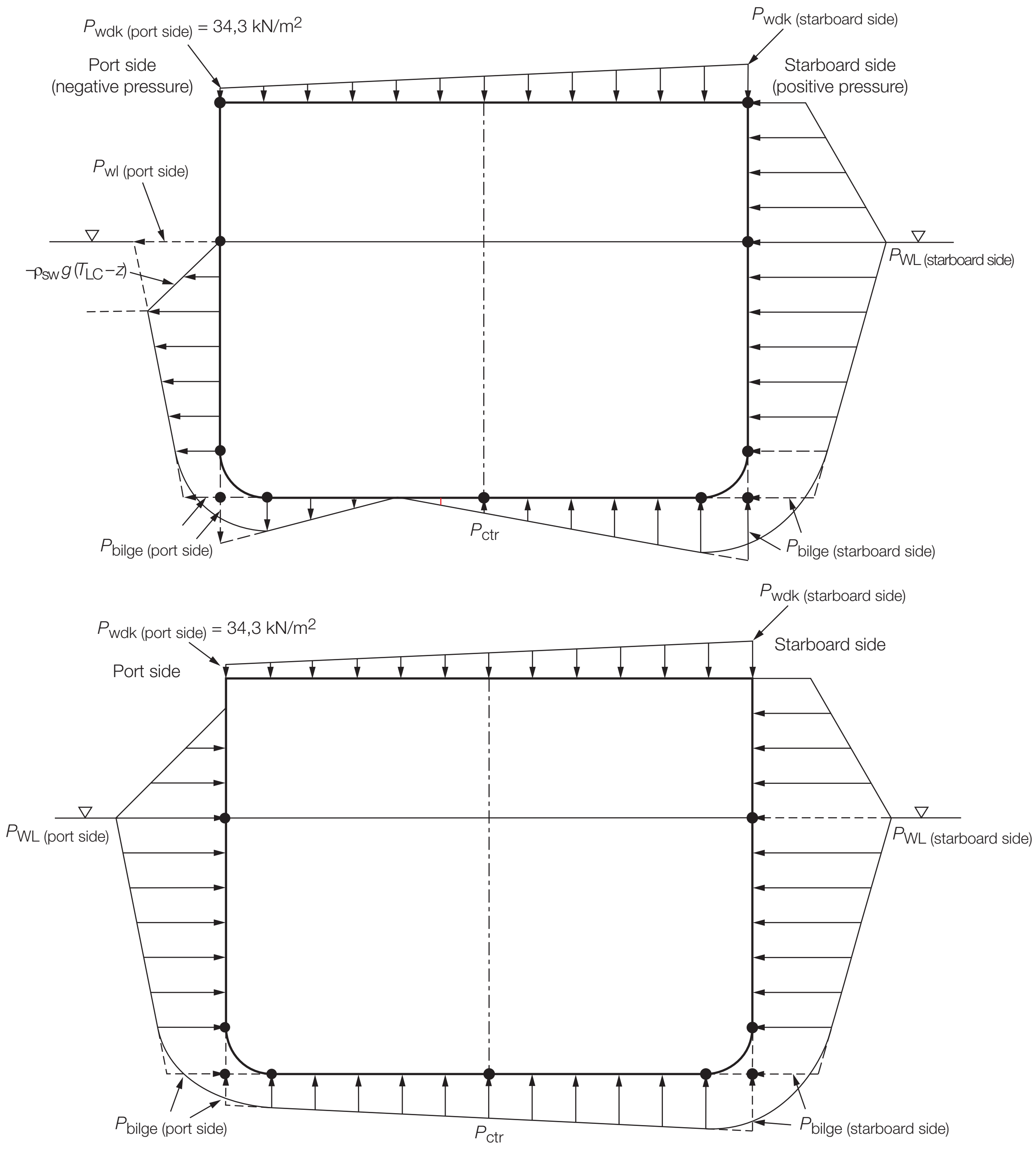

$P_{wdk\ (port\ side)}$ = 34,3 kN/m^2
$P_{wdk\ (starboard\ side)}$
Port side
(negative pressure)
Starboard side
(positive pressure)
$P_{wl\ (port\ side)}$
$-\rho_{sw}\, g\, (T_{LC} - z)$
$P_{WL\ (starboard\ side)}$
$P_{bilge\ (port\ side)}$
P_{ctr}
$P_{bilge\ (starboard\ side)}$
$P_{wdk\ (starboard\ side)}$
$P_{wdk\ (port\ side)}$ = 34,3 kN/m^2
Port side
Starboard side
$P_{WL\ (port\ side)}$
$P_{WL\ (starboard\ side)}$
$P_{bilge\ (port\ side)}$
P_{ctr}
$P_{bilge\ (starboard\ side)}$

Fig. 2.6.2 Dynamic wave pressure for beam sea dynamic load cases

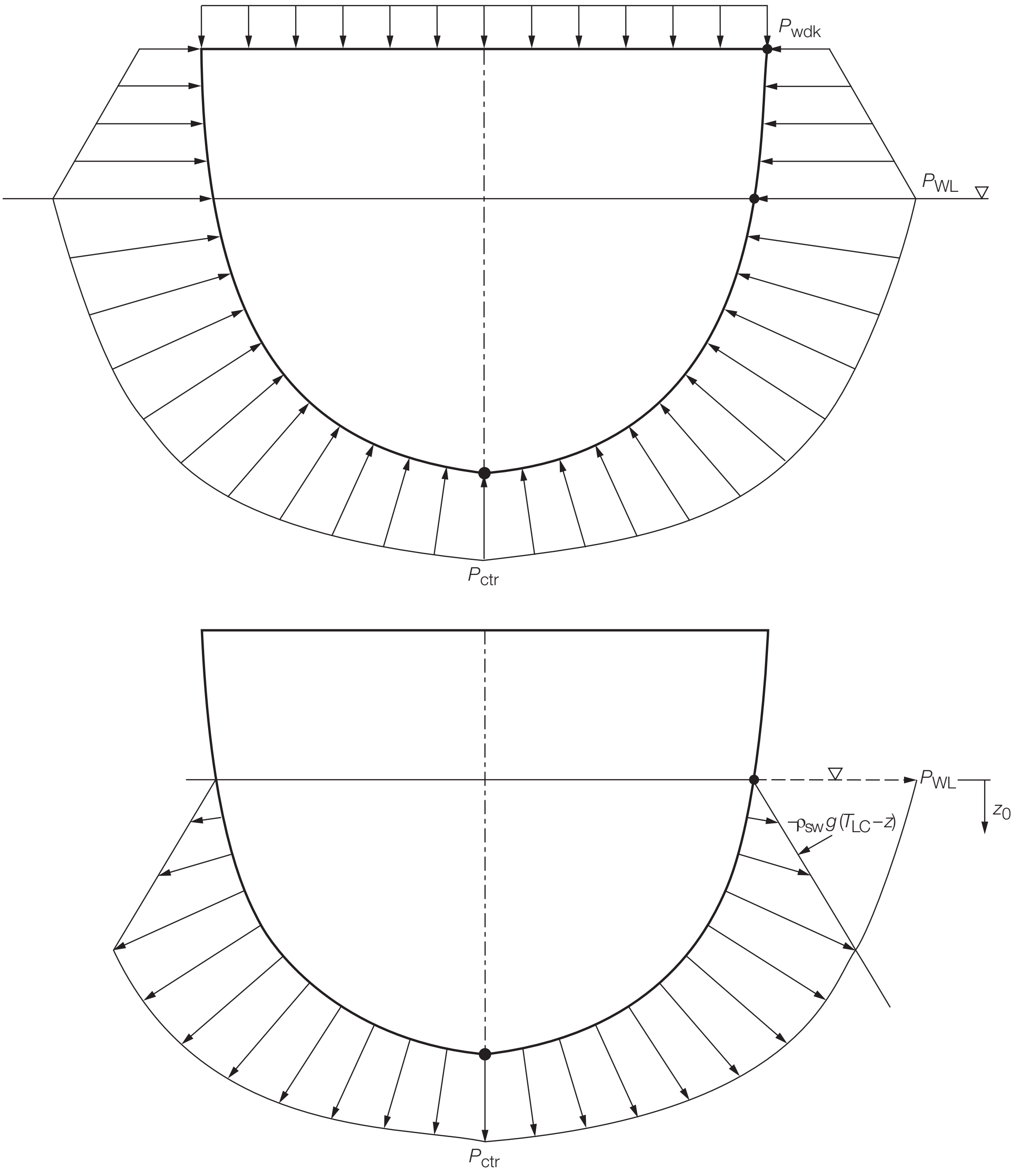


Fig. 2.6.3 Pressure distribution for wave crest and wave trough for forward and aft

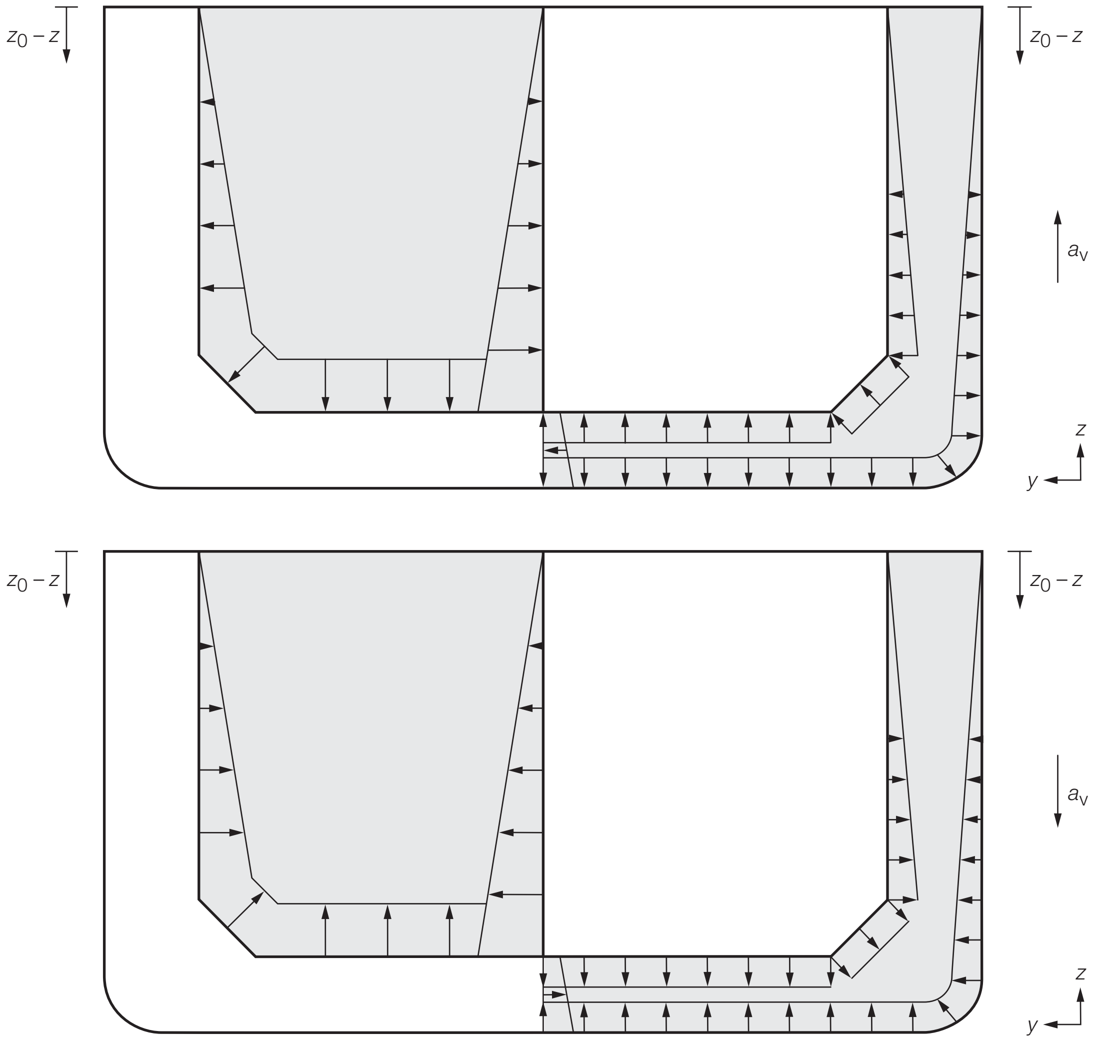


Fig. 2.6.4
Dynamic tank pressure in cargo tank (Left) and ballast tank (Right) due to positive and negative vertical tank acceleration

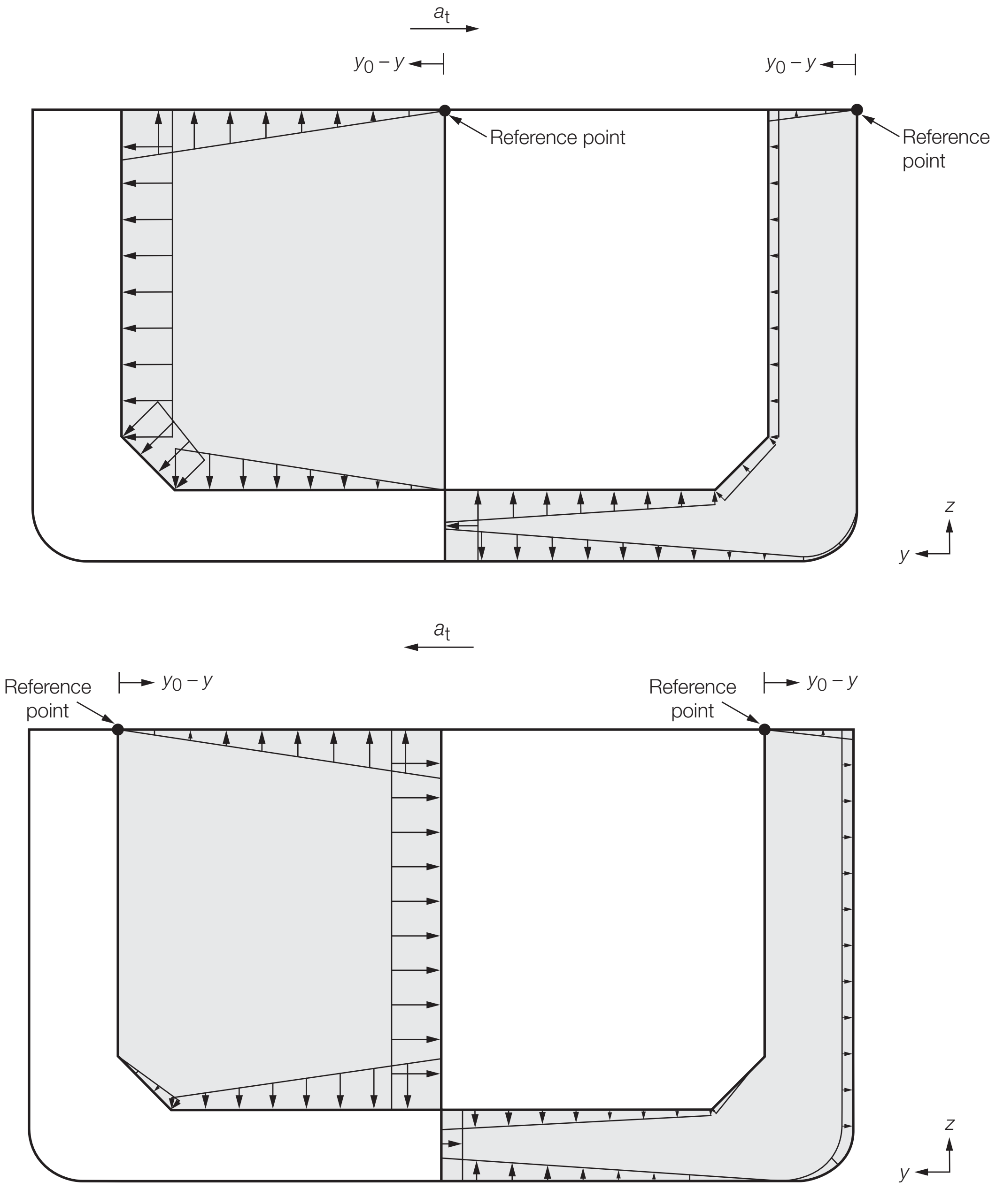


Fig. 2.6.5
Dynamic tank pressure in cargo tank (Left) and ballast tank (Right) due to negative and positive transverse tank acceleration

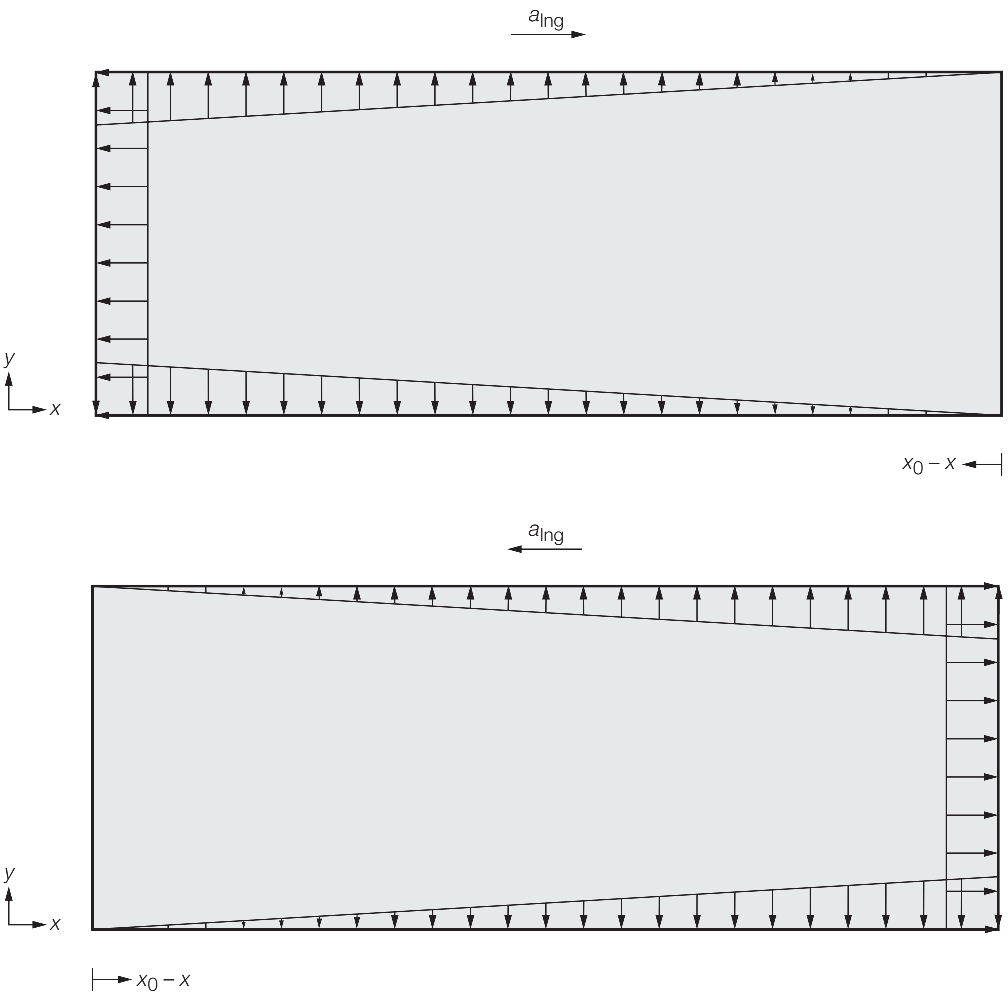


Fig. 2.6.6 Dynamic tank pressure in tanks due to positive and negative longitudinal acceleration

■ *Section 7*

Environmental loads for transit/disconnected condition

7.1 Dynamic load cases and dynamic load combination factors for strength assessment

7.1.1 **General**.

7.1.1.1 For the strength assessment (by FEM) the dynamic load cases given in Table 2.7.2 are to be applied. The simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in Table 2.7.2.

7.2 Dynamic load cases and dynamic load combination for scantling requirements

7.2.1 **General**.

7.2.1.1 For the scantling requirements, the dynamic load cases are to be applied in accordance with the design load sets for the design load combination $S + D$. The simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in Table 2.7.3 to Table 2.7.8, where world wide loads are used.

7.2.1.2 The Dynamic Load Combination Factor (DLCF) Table to be used depends on the longitudinal position being considered and is specified in Fig. 2.7.1 and Table 2.7.1.

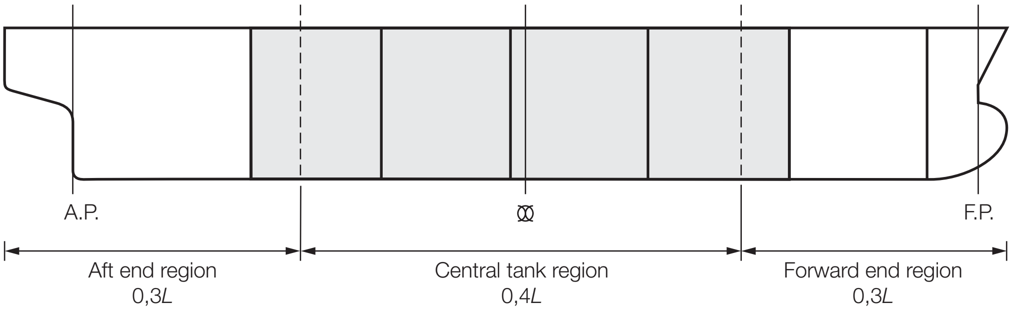


Fig. 2.7.1 Illustration of structural regions

Table 2.7.1 Dynamic load combination factor tables to be used for the scantling assessment

Structural region	Aft end region	Central tank region	Forward end region
Applicable for tanks and spaces	where the tank or space LCG is aft of 0,3*L*	where the tank or space LCG is between 0.3*L* and 0,7*L* inclusive	where the tank LCG is forward of 0,7*L*
For application to the ‘transit under tow’ and ‘transit or sea-going’ conditions, *see* Table 2.3.2 and Table 2.3.3			
Deep draught DLCF	Table 2.7.7	Table 2.7.3	Table 2.7.5
Light Draught DLCF	Table 2.7.8	Table 2.7.4	Table 2.7.6

7.2.1.3 Each dynamic load case in the DLCF tables maximises one or more dynamic load components. The minimised dynamic load components are to be calculated by multiplying all the dynamic load combination factors for a dynamic load case by –1,0. The scantling requirements are to be evaluated for all maximised and minimised dynamic load cases.

Table 2.7.2 Dynamic load cases for strength assessment (by FEM)

Wave direction			Head sea				Beam sea		Oblique sea	
Max. response			M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Sagging)	Q_{wv} (Hogging)	a_v		$M_{wv\text{-}h}$ (Hogging)	
Dynamic load case			1	2	3	4	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	–1,0	1,0	–1,0	1,0	0,4	–0,4	–0,2	0,4
	Q_{wv}	f_{qv}	1,0	–1,0	1,0	–1,0	–0,2	0,2	0,2	0,0
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	0,1	–0,1	0,2	–0,2	1,0	–1,0
Accelerations	a_v	f_v	0,6	–0,6	0,6	–0,6	1,0	–1,0	0,0	–0,1
	a_t	f_t	0,0	0,0	–0,1	0,1	0,2	–0,2	0,0	0,0
	a_{lng}	f_{lng}	–0,3	0,3	0,3	–0,3	–0,1	–0,1	0,4	0,5
Dynamic wave pressure for port side	P_{WL}	f_{WL}	–0,5	0,5	–0,5	0,5	–0,2	–0,7	0,1	0,3
	P_{bilge}	f_{bilge}	–0,2	0.,2	–0,2	0,2	–0,5	–1,0	0,1	0,4
	P_{ctr}	f_{ctr}	–0,4	0,4	–0,4	0,4	–0,9	–1,0	–0,2	0,3
Dynamic wave pressure for starboard side	P_{WL}	f_{WL}	–0,5	0,5	–0,5	0,5	–0,7	–0,2	0,3	0,1
	P_{bilge}	f_{bilge}	–0,2	0,2	–0,2	0,2	–1,0	–0,5	0,4	0,1
	P_{ctr}	f_{ctr}	–0,4	0,4	–0,4	0,4	–1,0	–0,9	0,3	–0,2
Symbols are as defined in 3.1, 6.1, 6.3.4 and Table 2.6.1.										

Table 2.7.3 Dynamic load cases for central tank region for deep draught condition

Wave direction			Head sea		Beam sea					
Max. response			M_{wv}	a_v	a_t		P_{ctr}		P_{WL}	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P
Global loads	M_{wv}	f_{mv}	1,0	–1,0	–0,1	–0,1	–0,2	–0,2	–0,3	–0,3
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	–0,1	0,1	0,0	0,0	0,0	0,0
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	–0,2	0,5	0,5	0,5	1,0	1,0	1,0	1,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	–0,2	0,5	0,2	0,6	0,8	1,0	0,8	1,0
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	–0,2	0,5	0,6	0,2	1,0	0,8	1,0	0,8
	a_t	f_t	0,0	0,0	1,0	–1,0	0,5	–0,5	0,6	–0,6
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	0,7	–0,6	0,5	0,5	1,0	1,0	0,9	0,9
	P_{bilge}	f_{bilge}	0,3	–0,2	0,8	–0,3	0,9	0,4	1,0	0,4
	P_{WL}	f_{WL}	0,3	–0,3	0,5	–0,2	0,8	0,4	1,0	0,4
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	0,7	–0,6	0,5	0,5	1,0	1,0	0,9	0,9
	P_{bilge}	f_{bilge}	0,3	–0,2	–0,3	0,8	0,4	0,9	0,4	1,0
	P_{WL}	f_{WL}	0,3	–0,3	–0,2	0,5	0,4	0,8	0,4	1,0

Symbols are as defined in 3.1, 6.1, 6.3.4, Table 2.6.1 and below

$a_{v\text{-}pt}$ = vertical acceleration for port tank, in m/s^2
$a_{v\text{-}stb}$ = vertical acceleration for starboard tank, in m/s^2
$a_{lng\text{-}mid}$ = longitudinal acceleration for centre tank, in m/s^2
$a_{lng\text{-}pt}$ = longitudinal acceleration for port tank, in m/s^2
$a_{lng\text{-}stb}$ = longitudinal acceleration for starboard tank, in m/s^2
$a_{lng\text{-}ctr}$ = longitudinal acceleration for centre double bottom ballast tank, in m/s^2
$f_{v\text{-}mid}$ = dynamic load combination factor associated with the vertical acceleration of a centre cargo and ballast tank
$f_{v\text{-}pt}$ = dynamic load combination factor associated with the vertical acceleration of a port cargo and side ballast tank
$f_{v\text{-}stb}$ = dynamic load combination factor associated with the vertical acceleration of a starboard cargo and side ballast tank
$f_{lng\text{-}pt}$ = dynamic load combination factor associated with the longitudinal acceleration of a port side cargo or ballast tank
$f_{lng\text{-}stb}$ = dynamic load combination factor associated with the longitudinal acceleration of a starboard side cargo or ballast tank
$f_{lng\text{-}ctr}$ = dynamic load combination factor associated with the longitudinal acceleration of a centre double bottom ballast tank
$f_{lng\text{-}mid}$ = dynamic load combination factor associated with the longitudinal acceleration of a centre tank

Table 2.7.4 Dynamic load cases for central tank region for light draught condition

Wave direction			Head sea		Beam sea					
Max. response			M_{wv}	a_v	a_t		P_{ctr}		P_{WL}	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P
Global loads	M_{wv}	f_{mv}	1,0	–1,0	–0,1	–0,1	–0,2	–0,2	–0,2	–0,2
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	0,1	–0,1	–0,1	0,1	–0,2	0,2
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	–0,1	0,4	0,5	0,5	1,0	1,0	1,0	1,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	–0,1	0,4	0,1	0,8	0,7	1,0	0,6	1,0
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	–0,1	0,4	0,8	0,1	1,0	0,7	1,0	0,6
	a_t	f_t	0,0	0,0	1,0	–1,0	0,8	–0,8	0,6	–0,6
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1,0	–0,8	0,3	0,3	0,8	0,8	0,4	0,4
	P_{bilge}	f_{bilge}	0,3	–0,2	0,9	–0,4	0,9	0,3	0,9	0,2
	P_{WL}	f_{WL}	0,3	–0,2	0,7	–0,4	0,9	0,2	1,0	0,2
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1,0	–0,8	0,3	0,3	0,8	0,8	0,4	0,4
	P_{bilge}	f_{bilge}	0,3	–0,2	–0,4	0,9	0,3	0,9	0,2	0,9
	P_{WL}	f_{WL}	0,3	–0,2	–0,4	0,7	0,2	0,7	0,2	1,0
Symbols are as defined in 3.1, 6.1, 6.3.4, Table 2.6.1 and Table 2.7.3										

Table 2.7.5 Dynamic load cases for forward end region for deep draught condition

Wave direction			Head sea		Oblique sea				Beam Sea	
Max. response			a_v	a_{lng}	P_{bilge}		P_{WL}		a_v	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P
Global loads	M_{wv}	f_{mv}	–0,7	0,9	–0,3	–0,3	–0,4	–0,4	–0,4	–0,4
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	–0,1	–0,1	0,2	–0,2	–0,1	0,1
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,7	–0,6	0,9	0,9	0,7	0,7	1,0	1,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,7	–0,6	0,9	1,0	0,7	0,7	0,9	1,0
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,7	–0,6	1,0	0,9	0,7	0,7	1,0	0,9
	a_t	f_t	0,0	0,0	0,7	–0,7	0,5	–0,5	0,6	–0,6
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,8	1,0	–0,5	–0,5	–1,0	–1,0	–0,5	–0,5
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,8	1,0	–0,5	–0,5	–1,0	–0,7	–0,5	–0,5
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,8	1,0	–0,5	–0,5	–0,7	–1,0	–0,5	–0,5
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,8	1,0	–0,5	–0,5	–1,0	–1,0	–0,5	–0,5
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1,0	–0,9	0,8	0,8	0,5	0,5	0,8	0,8
	P_{bilge}	f_{bilge}	0,6	–0,7	1,0	0,5	0,7	0,3	1,0	0,5
	P_{WL}	f_{WL}	0,3	–0,5	0,9	0,4	1,0	0,2	0,9	0,4
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1,0	–0,9	0,8	0,8	0,5	0,5	0,8	0,8
	P_{bilge}	f_{bilge}	0,6	–0,7	0,5	1,0	0,3	0,7	0,5	1,0
	P_{WL}	f_{WL}	0,3	–0,5	0,4	0,9	0,2	1,0	0,4	0,9
Symbols are as defined in 3.1, 6.1, 6.3.4, Table 2.6.1 and Table 2.7.3										

Table 2.7.6 Dynamic load cases for forward end region for light draught condition

Wave direction			Head sea		Oblique sea				Beam sea	
Max. response			a_v	a_{lng}	P_{bilge}		P_{WL}		a_v	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P
Global loads	M_{wv}	f_{mv}	–0,8	0,9	–0,2	–0,2	–0,3	–0,3	–0,1	–0,1
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	–0,5	0,5	0,3	–0,3	–0,4	0,4
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,7	–0,6	0,6	0,6	0,9	0,9	1,0	1,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,7	–0,6	0,3	0,8	0,7	0,7	0,5	1,0
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,7	–0,6	0,8	0,3	0,7	0,7	1,0	0,5
	a_t	f_t	0,0	0,0	0,9	–0,9	0,2	–0,2	0,7	–0,7
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,9	1,0	–0,3	–0,3	–0,9	–0,9	0,0	0,0
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,9	1,0	–0,5	0,2	–0,9	–0,6	0,0	0,0
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,9	1,0	0,2	–0,5	–0,6	–0,9	0,0	0,0
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,9	1,0	–0,3	–0,3	–0,9	–0,9	0,0	0,0
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1,0	–0,7	0,6	0,6	0,6	0,6	0,4	0,4
	P_{bilge}	f_{bilge}	0,5	–0,4	1,0	–0,3	0,9	0,2	0,8	0,2
	P_{WL}	f_{WL}	0,3	–0,2	0,9	–0,3	1,0	0,1	0,8	0,2
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1,0	–0,7	0,6	0,6	0,6	0,6	0,4	0,4
	P_{bilge}	f_{bilge}	0,5	–0,4	–0,3	1,0	0,2	0,9	0,2	0,8
	P_{WL}	f_{WL}	0,3	–0,2	–0,3	0,9	0,1	1,0	0,2	0,8
Symbols are as defined in 3.1, 6.1, 6.3.4, Table 2.6.1 and Table 2.7.3										

Table 2.7.7 Dynamic load cases for aft end region for deep draught condition

Location			Aft end region							Forward end			
Wave direction			Following sea	Oblique sea		Beam sea				Beam sea			
Max. response			P_{ctr}	P_{WL}		a_v		a_t		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	–1,0	–0,7	–0,7	–0,4	–0,4	–0,1	–0,1	—	—	—	—
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,6	0,9	0,9	1,0	1,0	0,3	0,3	1,0	1,0	0,3	0,3
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,6	—	0,9	—	1,0	—	0,4	—	1,0	—	0,3
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,6	0,9	—	1,0	—	0,4	—	1,0	—	0,3	—
	a_t	f_t	0,0	0,2	–0,2	0,5	–0,5	1,0	–1,0	0,7	–0,7	1,0	–1,0
	a_{lng}	f_{lng}	0,8	0,7	0,7	0,6	0,6	–0,1	–0,1	–0,7	–0,7	–0,1	–0,1
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1,0	0,8	0,8	0,7	0,7	0,2	0,2	1,0	1,0	0,2	0,2
	P_{WL}	f_{WL}	0,5	1,0	0,2	0,8	0,3	0,5	–0,3	1,0	0,8	0,2	0,0
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1,0	0,8	0,8	0,7	0,7	0,2	0,2	1,0	1,0	0,2	0,2
	P_{WL}	f_{WL}	0,5	0,2	1,0	0,3	0,8	–0,3	0,5	0,8	1,0	0,0	0,2
Symbols are as defined in 3.1, 6.1, 6.3.4, Table 2.6.1 and Table 2.7.3													

Table 2.7.8 Dynamic load cases for aft end region for light draught condition

Location			Aft end region							Forward end			
Wave direction			Following sea	Oblique sea		Beam sea				Beam sea			
Max. response			P_{ctr}	P_{WL}		a_v		a_t		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	–1,0	–0,3	–0,3	0,2	0,2	0,1	0,1	—	—	—	—
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,6	0,9	0,9	1,0	1,0	0,3	0,3	1,0	1,0	0,3	0,3
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,6	—	0,9	—	1,0	—	0,5	—	1,0	—	0,5
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,6	0,9	—	1,0	—	0,5	—	1,0	—	0,5	—
	a_t	f_t	0,0	0,1	–0,1	0,6	–0,6	1,0	–1,0	0,7	–0,7	1,0	–1,0
	a_{lng}	f_{lng}	0,7	0,8	0,8	0,2	0,2	0,0	0,0	–0,3	–0,3	0,0	0,0
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1,0	0,7	0,7	0,5	0,5	0,1	0,1	0,6	0,6	0,1	0,1
	P_{WL}	f_{WL}	0,8	1,0	0,3	0,6	0,1	0,4	–0,3	0,7	0,3	0,3	–0,1
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1,0	0,7	0,7	0,5	0,5	0,1	0,1	0,6	0,6	0,1	0,1
	P_{WL}	f_{WL}	0,8	0,3	1,0	0,1	0,6	–0,3	0,4	0,3	0,7	–0,1	0,3
Symbols are as defined in 3.1, 6.1, 6.3.4, Table 2.6.1 and Table 2.7.3													

■ *Section 8*
Environmental loads for site-specific load scenarios

8.1 Symbols

M_{wv} = vertical wave bending moment
Q_{wv} = vertical wave shear force
$M_{wv\text{-}h}$ = horizontal wave bending moment
$a_{v\text{-}PS}$ = vertical acceleration, port side
$a_{t\text{-}PS}$ = transverse acceleration, port side
$a_{lng\text{-}PS}$ = longitudinal acceleration, port side
$a_{v\text{-}STB}$ = vertical acceleration, starboard side
$a_{t\text{-}STB}$ = transverse acceleration, starboard side
$a_{lng\text{-}STB}$ = longitudinal acceleration, starboard side
$a_{v\text{-}FP}$ = vertical acceleration, at F.P.
$a_{t\text{-}FP}$ = transverse acceleration, at F.P.
$a_{lng\text{-}FP}$ = longitudinal acceleration, at F.P.
$P_{WL\text{-}PS}$ = dynamic pressure at waterline, port side. Note this may be taken as equivalent to the relative wave elevation
$P_{bilge\text{-}PS}$ = dynamic pressure at bilge, port side
$P_{ctr\text{-}PS}$ = dynamic pressure at bottom centre, on the port side facet
$P_{WL\text{-}STB}$ = dynamic pressure at waterline, starboard side. Note this may be taken as equivalent to the relative wave elevation
$P_{bilge\text{-}STB}$ = dynamic pressure at bilge, on the starboard side facet
$P_{ctr\text{-}STB}$ = dynamic pressure at bottom centre, on the starboard side facet
$P_{WL\text{-}FP}$ = dynamic pressure at waterline, at F.P. on centreline. Note this may be taken as equivalent to the relative wave elevation.

8.2 General

8.2.1 **Application**.

8.2.1.1 This Section gives the dynamic load combination factors which are to be used in the derivation of the local and global design loads for the site-specific on-site operational condition. The DLCF Tables for the operational condition may be used for the initial design of units for the maintenance case. The deep draught DLCF Table for the operational condition may be used for the initial design of units for the flooded case.

8.2.1.2 The environmental loads include natural phenomena such as wind, wave and currents and also ice and thermal conditions.

8.2.1.3 Alternative methods of establishing the environmental loads will be specially considered, provided that they are based on hindcast data, long-term measurements, global and local environmental theoretical models, or similar techniques. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

8.2.1.4 In order that an assessment of the design requirements can be made, the following information is to be submitted:
(a) Service area notation required together with the required extent of the operational area.
(b) The wave environmental parameters for the design.
(c) Specification of the environmental conditions used for the design assessment.

8.2.2 **Direct calculations**.

8.2.2.1 The assessment of environmental loads may be based on the results of model tests and/or by suitable direct calculation methods of the actual loads on the hull at the site-specific location, taking into account the following service-related factors:
- Site-specific environmental loads.
- Mooring system and riser loads.
- Unit orientation and wave loading directions.
- Long-term service effects at a fixed location.
- Range of tank-loading conditions including empty tanks required for on-station surveys.

8.2.2.2 The derivation of the wave environmental parameters is to be in accordance with the data specification and methods given. The areas used for the direct calculation will then be specified, based on the operational service area restriction notation.

8.3 Dynamic load combination factors for site-specific on-site operation

8.3.1 **General**.

8.3.1.1 The DLCF Table to be used depends on the longitudinal position being considered, as specified in Fig. 2.7.1 and Table 2.8.1.

8.3.1.2 For the strength assessment (by FEM) the appropriate site-specific dynamic load cases given in Tables 2.8.2, 2.8.9, 2.8.16 and 2.8.23 are to be applied.

8.3.1.3 The site-specific loads are to be derived using the appropriate site-specific dynamic load combination factors given in Tables 2.8.3 to 2.8.29. The Tables give the dynamic load combination factors for the hogging condition. It is necessary to also carry out the scantling assessment for the sagging condition, therefore multiplying all values by minus one.

Table 2.8.1 Dynamic load combination factor Tables to be used for the scantling assessment

Structural region	Aft end region	Central tank region	Forward end region
Applicable for tanks and spaces	where the tank or space LCG is aft of 0,3*L*	where the tank or space LCG is between 0,3*L* and 0,7*L* inclusive	where the tank LCG is forward of 0,7*L*
For application to the loading conditions, *see* Table 2.3.2 and Table 2.3.3 **West of Shetland Is., aframax weather vaning unit**			
Deep draught DLCF	Table 2.8.7	Table 2.8.3	Table 2.8.5
Light draught DLCF	Table 2.8.8	Table 2.8.4	Table 2.8.6
For application to the loading conditions, *see* Table 2.3.2 and Table 2.3.3 **North Sea, aframax weather vaning unit**			
Deep draught DLCF	Table 2.8.14	Table 2.8.10	Table 2.8.12
Light draught DLCF	Table 2.8.15	Table 2.8.11	Table 2.8.13
For application to the loading conditions, *see* Table 2.3.2 and Table 2.3.3 **Brazil, aframax weather vaning unit**			
Deep draught DLCF	Table 2.8.21	Table 2.8.17	Table 2.8.19
Light draught DLCF	Table 2.8.22	Table 2.8.18	Table 2.8.20
For application to the loading conditions, *see* Table 2.3.2 and Table 2.3.3 **Western Australia (non-cyclonic), aframax weather vaning unit**			
Deep draught DLCF	Table 2.8.28	Table 2.8.24	Table 2.8.26
Light draught DLCF	Table 2.8.29	Table 2.8.25	Table 2.8.27
DLCFs for VLCC weather vaning units, aframax and VLCC spread moored units TBA			
NOTE The symbols in the DCLF tables are defined in 3.1, 6.1, 7.1, 6.3.4, Table 2.6.1 and Table 2.7.3.			

TBA: Factor will be advised by LR upon request.

Table 2.8.2 Dynamic load cases for strength assessment (by FEM) for a weather vaning aframax unit, West of Shetland Is.

Max. response			M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Sagging)	Q_{wv} (Hogging)	a_v		$M_{wv\text{-}h}$ (Hogging)	
Dynamic load case			1	2	3	4	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	–1,0	1,0	–0,9	0,9	0,4	0,4	0,2	0,2
	Q_{wv}	f_{qv}	1,0	–1,0	1,0	–1,0	–0,2	–0,2	–0,2	–0,2
	$M_{wv\text{-}h}$	f_{mh}	0,1	–0,1	0,0	0,0	0,2	–0,2	–1,0	1,0
Accelerations	a_v	f_v	–0,6	0,6	–0,2	0,2	1,0	1,0	0,0	0,0
	a_t	f_t	0,0	0,0	0,0	0,0	0,2	–0,2	0,0	0,0
	a_{lng}	f_{lng}	0,6	–0,6	0,1	–0,1	–0,1	–0,1	0,6	0,6
Dynamic wave pressure for port side	P_{WL}	f_{WL}	–0,8	0,8	–0,8	0,8	–0,2	–0,7	–0,1	0,3
	P_{bilge}	f_{bilge}	–0,5	0,5	–0,5	0,5	–0,5	–1,0	–0,1	0,4
	P_{ctr}	f_{ctr}	–1,0	1,0	–1,0	1,0	–0,9	–1,0	0,2	0,2
Dynamic wave pressure for starboard side	P_{WL}	f_{WL}	–0,8	0,8	–0,8	0,8	–0,7	–0,2	0,3	–0,1
	P_{bilge}	f_{bilge}	–0,5	0,5	–0,5	0,5	–1,0	–0,5	0,4	–0,1
	P_{ctr}	f_{ctr}	–1,0	1,0	–1,0	1,0	–1,0	–0,9	0,2	0,2

Table 2.8.3 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, West of Shetland Is.

Max. response			M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case			1 (Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
Global load	M_{wv}	f_{mv}	1,0	0,4	–0,6	–0,2	–0,2	0,1	0,1	0,8	0,8	–0,2	–0,2
	$M_{wv\text{-}h}$	f_{mh}	–0,1	0,2	0,3	–1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,5	1,0	–0,6	–0,1	–0,1	0,3	0,3	0,1	0,1	–0,1	–0,1
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,5	1,0	–0,6	–0,1	–0,1	0,1	0,5	0,1	0,1	–0,1	–0,1
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,5	1,0	–0,6	–0,1	–0,1	0,5	0,1	0,1	0,1	–0,1	–0,1
	a_t	f_t	0,0	0,2	0,0	0,1	–0,1	1,0	–0,1	0,0	0,0	0,0	0,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,6	0,1	1,0	0,4	0,4	0,0	0,0	–0,3	–0,3	0,4	0,4
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,6	0,1	1,0	0,4	0,4	–0,1	0,1	–0,3	–0,3	0,4	0,4
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,6	0,1	1,0	0,4	0,4	0,1	–0,1	–0,3	–0,3	0,4	0,4
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,6	0,1	1,0	0,4	0,4	0,0	0,0	–0,3	–0,3	0,4	0,4
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	1,0	–1,0	–0,2	–0,3	–0,2	–0,4	–0,1	1,0	1,0	0,3	0,3
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,5	–1,0	–0,1	–0,4	0,1	–1,0	0,6	0,7	0,6	0,4	0,4
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,8	–0,7	–0,2	–0,3	0,1	–0,8	0,7	1,0	0,9	0,9	1,0
Dynamic wave pressure on port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	1,0	–1,0	–0,2	–0,2	–0,3	–0,1	–0,4	1,0	1,0	0,3	0,3
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,5	–1,0	–0,1	0,1	–0,4	0,6	–1,0	0,6	0,7	0,4	0,4
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,8	–0,7	–0,2	0,1	–0,3	0,7	–0,8	0,9	1,0	1,0	0,9

Table 2.8.4 **Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, West of Shetland Is.**

Max. response			M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case			1 (Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
Global loads	M_{wv}	f_{mv}	1,0	0,1	–0,4	–0,4	–0,4	0,2	0,2	0,8	0,8	0,5	0,5
	$M_{wv\text{-}h}$	f_{mh}	–0,6	0,0	0,0	–0,1	1,0	–0,8	0,8	0,0	0,0	0,0	0,0
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,3	1,0	–0,5	–0,5	–0,5	0,3	0,3	0,1	0,1	–0,5	–0,5
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,3	1,0	–0,5	–0,5	–0,5	0,1	0,5	0,1	0,1	–0,5	–0,5
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,3	1,0	–0,5	–0,5	–0,5	0,5	0,1	0,1	0,1	–0,5	–0,5
	a_t	f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	1,0	–0,4	–0,4	–0,4	–0,3	–0,1	0,2	1,0	1,0	0,9	0,9
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,6	–0,5	–0,2	–0,6	0,2	–0,7	0,7	0,7	0,6	0,7	0,8
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,8	–0,9	–0,1	–0,2	0,3	–0,5	0,7	0,8	0,8	1,0	1,0
Dynamic wave pressure on port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	1,0	–0,4	–0,4	–0,3	–0,4	0,2	–0,1	1,0	1,0	0,9	0,9
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,6	–0,5	–0,2	0,2	–0,6	0,7	–0,7	0,6	0,7	0,8	0,7
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,8	–0,9	–0,1	0,3	–0,2	0,7	–0,5	0,8	0,8	1,0	1,0

Table 2.8.5 **Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, West of Shetland Is.**

Max. response			a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	0,7	–0,8	–1,0	–1,0	–1,0	–1,0	–0,9	–0,9	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	0,1	0,0	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,0	0,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	–0,1	0,1
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,1	–0,1
	a_t	f_t	0,1	0,0	0,0	0,0	0,1	–0,1	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,9	0,9	–0,1	0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–1,0	0,8	0,9	0,8	0,8	1,0	0,8	0,8	–0,5	0,4
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–0,5	0,5	0,8	0,7	0,7	0,8	1,0	1,0	–0,5	0,4
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,9	0,9	0,1	–0,1
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–1,0	0,8	0,8	0,9	1,0	0,8	0,8	0,8	0,4	–0,5
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–0,5	0,5	0,7	0,8	0,8	0,7	1,0	1,0	0,4	–0,5

Table 2.8.6 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, West of Shetland Is.

Max. response			a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	0,8	–0,8	–1,0	–1,0	–1,0	–1,0	–0,9	–0,9	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	1,0	–0,8	–0,9	–0,9	–0,9	–0,9	–0,4	–0,4	0,0	0,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	1,0	–0,8	–0,9	–0,9	–0,9	–0,9	–0,4	–0,4	–0,1	0,1
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	1,0	–0,8	–0,9	–0,9	–0,9	–0,9	–0,4	–0,4	0,1	–0,1
	a_t	f_t	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–0,9	0,7	1,0	1,0	1,0	1,0	0,8	0,9	–0,2	0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–0,7	0,6	0,8	0,8	1,0	1,0	0,8	0,8	–0,7	0,6
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–0,5	0,4	0,7	0,8	1,0	0,9	1,0	1,0	–0,6	0,5
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–0,9	0,7	1,0	1,0	1,0	1,0	0,9	0,8	0,1	–0,2
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–0,7	0,6	0,8	0,8	1,0	1,0	0,8	0,8	0,6	–0,7
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–0,5	0,4	0,8	0,7	0,9	1,0	1,0	1,0	0,5	–0,6

Table 2.8.7 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, West of Shetland Is.

Max. response			P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P
Global loads	M_{wv}	f_{mv}	–0,5	–0,2	–0,2	0,5	0,5	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	–0,7	0,3	0,3	0,7	0,7	0,3	0,3
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	–1,0	–0,3	–0,3	1,0	1,0	0,2	0,2
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	–1,0	–0,3	–0,3	1,0	1,0	0,1	0,3
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	–1,0	–0,3	–0,3	1,0	1,0	0,3	0,1
	a_t	f_t	0,2	0,0	0,0	–0,2	0,2	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	1,0	0,4	0,5	–1,0	–0,9	–0,3	–0,2
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	1,0	0,5	0,7	–0,9	–0,7	–0,8	0,4
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,7	1,0	1,0	–0,7	–0,4	–0,6	0,4
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	1,0	0,5	0,4	–0,9	–1,0	–0,2	–0,3
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	1,0	0,7	0,5	–0,7	–0,9	0,4	–0,8
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,7	1,0	1,0	–0,4	–0,7	0,4	–0,6

Table 2.8.8 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, West of Shetland Is.

Max. response			P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P
Global loads	M_{wv}	f_{mv}	–0,1	–0,1	–0,1	0,4	0,4	0,3	0,3
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	0,0	0,0	0,0	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	–0,5	–0,3	–0,3	1,0	1,0	0,5	0,5
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	–0,5	–0,3	–0,3	1,0	1,0	0,4	0,6
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	–0,5	–0,3	–0,3	1,0	1,0	0,6	0,4
	a_t	f_t	0,0	0,0	0,0	0,0	0,0	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	1,0	0,5	0,5	–0,4	–0,4	–0,8	–0,4
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	1,0	0,5	0,5	–0,1	–0,1	–0,9	0,5
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	1,0	1,0	1,0	0,1	0,1	–0,8	0,6
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	1,0	0,5	0,5	–0,4	–0,4	–0,4	–0,8
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	1,0	0,5	0,5	–0,1	–0,1	0,5	–0,9
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	1,0	1,0	1,0	0,1	0,1	0,6	–0,8

Table 2.8.9 Dynamic load cases for strength assessment (by FEM) for a weather vaning aframax unit, North Sea

Max. response			M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Sagging)	Q_{wv} (Hogging)	a_v		$M_{wv\text{-}h}$ (Hogging)	
Dynamic load case			1	2	3	4	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	–1,0	1,0	–0,8	0,8	0,3	0,3	–0,3	–0,3
	Q_{wv}	f_{qv}	0,8	–0,8	1,0	–1,0	–0,2	0,2	–0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	0,3	–0,3	0,1	–0,1	–0,1	–0,1	1,0	1,0
Accelerations	a_v	f_v	–0,7	0,7	–0,1	0,1	1,0	1,0	–0,3	–0,3
	a_t	f_t	–0,1	0,1	0,0	0,0	0,3	–0,3	0,1	–0,1
	a_{lng}	f_{lng}	0,9	–0,9	0,2	–0,2	–0,1	–0,1	0,4	0,4
Dynamic wave pressure for port side	P_{WL}	f_{WL}	–0,8	0,8	–1,0	1,0	–0,2	–0,5	0,1	–0,2
	P_{bilge}	f_{bilge}	–0,6	0,6	–0,9	0,9	–0,6	–0,9	0,2	–0,3
	P_{ctr}	f_{ctr}	–1,0	1,0	–1,0	1,0	–0,9	–0,9	–0,1	–0,2
Dynamic wave pressure for starboard side	P_{WL}	f_{WL}	–0,8	0,8	–1,0	1,0	–0,5	–0,2	–0,2	0,1
	P_{bilge}	f_{bilge}	–0,6	0,6	–0,9	0,9	–0,9	–0,6	–0,3	0,2
	P_{ctr}	f_{ctr}	–1,0	1,0	–1,0	1,0	–0,9	–0,9	–0,2	–0,1

Table 2.8.10 **Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, North Sea**

Max. response			M_{wv}	a_v	a_{lng}	M_{wv-h}		a_t		P_{ctr}		P_{WL}	
Dynamic load case			1 (Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
Global loads	M_{wv}	f_{mv}	1,0	0,3	–0,6	–0,3	–0,3	0,1	0,1	0,6	0,6	–0,2	–0,2
	M_{wv-h}	f_{mh}	–0,3	–0,1	–0,3	–1,0	1,0	–0,1	0,1	–0,1	0,1	–0,1	0,1
Accelerations	a_{v-mid}	f_{v-mid}	0,7	1,0	–0,8	–0,3	–0,3	0,3	0,3	0,1	0,1	–0,2	–0,2
	a_{v-pt}	f_{v-pt}	0,7	1,0	–0,8	–0,3	–0,3	0,1	0,4	0,1	0,1	–0,2	–0,2
	a_{v-stb}	f_{v-stb}	0,7	1,0	–0,8	–0,3	–0,3	0,4	0,1	0,1	0,1	–0,2	–0,2
	a_t	f_t	0,1	0,3	0,1	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
	$a_{lng-mid}$	$f_{lng-mid}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
	a_{lng-pt}	f_{lng-pt}	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
	$a_{lng-stb}$	$f_{lng-stb}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
	$a_{lng-ctr}$	$f_{lng-ctr}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
Dynamic wave pressure for starboard side	$P_{ctr-STB}$	$f_{ctr-STB}$	1,0	–0,9	–0,2	–0,2	–0,1	–0,4	–0,1	1,0	1,0	0,4	0,4
	$P_{bilge-STB}$	$f_{bilge-STB}$	0,6	–0,9	–0,1	–0,3	0,2	–0,9	0,8	0,6	0,7	0,5	0,5
	P_{WL-STB}	f_{WL-STB}	0,8	–0,5	–0,2	–0,2	0,1	–0,6	0,6	0,8	0,9	1,0	1,0
Dynamic wave pressure for port side	P_{ctr-PS}	f_{ctr-PS}	1,0	–0,9	–0,2	–0,1	–0,2	–0,1	–0,4	1,0	1,0	0,4	0,4
	$P_{bilge-PS}$	$f_{bilge-PS}$	0,6	–0,9	–0,1	0,2	–0,3	0,8	–0,9	0,7	0,6	0,5	0,5
	P_{WL-PS}	f_{WL-PS}	0,8	–0,5	–0,2	0,1	–0,2	0,6	–0,6	0,9	0,8	1,0	1,0

Table 2.8.11 **Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, North Sea**

Max. response			M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case			1 (Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
Global loads	M_{wv}	f_{mv}	1,0	0,4	–0,5	–0,7	–0,7	0,1	0,1	0,7	0,7	0,4	0,4
	$M_{wv\text{-}h}$	f_{mh}	–0,2	–0,8	0,6	–1,0	1,0	–0,8	0,8	–0,2	0,2	–0,2	0,2
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,2	1,0	–0,4	–0,9	–0,9	0,3	0,3	–0,1	–0,1	–0,6	–0,6
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,2	1,0	–0,4	–0,9	–0,9	0,1	0,5	–0,1	–0,1	–0,6	–0,6
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,2	1,0	–0,4	–0,9	–0,9	0,5	0,1	–0,1	–0,1	–0,6	–0,6
	a_t	f_t	0,1	0,1	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	1,0	–0,1	–0,5	–0,7	–0,5	–0,4	0,2	1,0	1,0	0,9	0,9
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,6	–0,6	–0,4	–0,7	0,2	–0,8	0,8	0,7	0,4	0,7	0,5
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,8	–1,0	–0,3	–0,2	0,4	–0,8	0,8	0,7	0,7	1,0	1,0
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	1,0	–0,1	–0,5	–0,5	–0,7	0,2	–0,4	1,0	1,0	0,9	0,9
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,6	–0,6	–0,4	0,2	–0,7	0,8	–0,8	0,4	0,7	0,5	0,7
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,8	–1,0	–0,3	0,4	–0,2	0,8	–0,8	0,7	0,7	1,0	1,0

Table 2.8.12 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, North Sea

Max. response			a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,0	0,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	–0,1	0,1
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,1	–0,1
	a_t	f_t	0,0	0,0	0,0	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–0,9	0,9	1,0	1,0	1,0	1,0	0,8	0,8	–0,1	0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	–0,4	0,4
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–0,8	0,8	1,0	0,9	1,0	0,9	1,0	1,0	–0,4	0,4
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–0,9	0,9	1,0	1,0	1,0	1,0	0,8	0,8	0,1	–0,1
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,4	–0,4
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–0,8	0,8	0,9	1,0	0,9	1,0	1,0	1,0	0,4	–0,4

Table 2.8.13 **Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, North Sea**

Max. response			a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,9	–0,9	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	0,1	0,1	–0,1	0,1	0,0	0,0	–0,1	0,1	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	1,0	–0,9	–0,9	–0,9	–1,0	–1,0	–0,5	–0,5	0,0	0,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	1,0	–0,9	–0,9	–0,9	–1,0	–1,0	–0,5	–0,5	–0,1	0,2
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	1,0	–0,9	–0,9	–0,9	–1,0	–1,0	–0,5	–0,5	0,2	0,1
	a_t	f_t	–0,1	0,1	0,1	–0,1	0,1	–0,1	0,0	0,0	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,8	0,8	–0,3	0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–0,9	0,8	0,9	0,5	0,6	1,0	0,8	0,4	–0,8	0,7
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–0,6	0,6	0,9	0,5	0,5	0,9	1,0	0,7	–0,8	0,7
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,8	0,8	0,1	–0,3
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–0,9	0,8	0,5	0,9	1,0	0,6	0,4	0,8	0,7	–0,8
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–0,6	0,6	0,5	0,9	0,9	0,5	0,7	1,0	0,7	–0,8

Table 2.8.14 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, North Sea

Max. response			P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P
Global loads	M_{wv}	f_{mv}	–0,4	–0,2	–0,2	0,3	0,3	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	–0,1	–0,3	0,3	–0,3	0,3	–0,1	0,1
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	–1,0	–0,1	–0,1	1,0	1,0	0,2	0,2
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	–1,0	–0,1	–0,1	1,0	1,0	0,1	0,3
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	–1,0	–0,1	–0,1	1,0	1,0	0,3	0,1
	a_t	f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	1,0	0,7	0,7	–1,0	–1,0	–0,3	–0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,9	0,6	0,6	–0,9	–0,7	–0,7	0,5
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,7	1,0	1,0	–0,7	–0,3	–0,5	0,5
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	1,0	0,7	0,7	–1,0	–1,0	–0,1	–0,3
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,9	0,6	0,6	–0,7	–0,9	0,5	–0,7
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,7	1,0	1,0	–0,3	–0,7	0,5	–0,5

Table 2.8.15 **Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, North Sea**

Max. response			P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P
Global loads	M_{wv}	f_{mv}	0,2	0,1	0,1	0,5	0,5	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	–0,2	–0,1	0,1	–0,2	0,2	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,1	–0,4	–0,4	1,0	1,0	0,3	0,3
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,1	–0,4	–0,4	1,0	1,0	0,1	0,4
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,1	–0,4	–0,4	1,0	1,0	0,4	0,1
	a_t	f_t	0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–1,0	0,4	0,4	–0,5	–0,6	–0,6	0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–1,0	0,6	0,3	–0,1	–0,2	–0,8	0,8
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–1,0	1,0	0,8	0,1	–0,1	–0,8	0,8
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–1,0	0,4	0,4	–0,6	–0,5	0,1	–0,6
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–1,0	0,3	0,6	–0,2	–0,1	0,8	–0,8
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–1,0	0,8	1,0	–0,1	0,1	0,8	–0,8

Table 2.8.16 **Dynamic load cases for strength assessment (by FEM) for a weather vaning aframax unit, Brazil**

Max. response			M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Sagging)	Q_{wv} (Hogging)	a_v		$M_{wv\text{-}h}$ (Hogging)	
Dynamic load case			1	2	3	4	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	–1,0	1,0	–0,8	0,8	0,4	0,4	–0,2	–0,2
	Q_{wv}	f_{qv}	0,9	–0,9	1,0	–1,0	–0,2	–0,2	0,2	0,2
	$M_{wv\text{-}h}$	f_{mh}	0,4	–0,4	–0,1	0,1	–0,2	0,2	–1,0	1,0
Accelerations	a_v	f_v	–0,5	0,5	–0,2	0,2	1,0	1,0	–0,1	–0,1
	a_t	f_t	–0,1	0,1	0,0	0,0	0,2	–0,2	0,1	–0,1
	a_{lng}	f_{lng}	1,0	–1,0	0,4	–0,4	–0,1	–0,1	0,4	0,4
Dynamic wave pressure for port side	P_{WL}	f_{WL}	–0,6	0,6	–0,8	0,8	–0,2	–0,5	0,1	–0,2
	P_{bilge}	f_{bilge}	–0,3	0,3	–0,4	0,4	–0,5	–0,6	0,1	–0,2
	P_{ctr}	f_{ctr}	–0,7	0,7	–0,8	0,8	–1,0	–1,0	–0,2	–0,2
Dynamic wave pressure for starboard side	P_{WL}	f_{WL}	–0,6	0,6	–0,8	0,8	–0,5	–0,2	–0,2	0,1
	P_{bilge}	f_{bilge}	–0,3	0,3	–0,4	0,4	–0,6	–0,5	–0,2	0,1
	P_{ctr}	f_{ctr}	–0,7	0,7	–0,8	0,8	–1,0	–1,0	–0,2	–0,2

Table 2.8.17 **Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, Brazil**

Max. response			M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case			1 (Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
Global loads	M_{wv}	f_{mv}	1,0	0,4	–0,6	–0,2	–0,2	0,1	0,1	–0,4	–0,4	–0,3	–0,3
	$M_{wv\text{-}h}$	f_{mh}	–0,4	0,2	0,7	–1,0	1,0	–0,1	0,1	–0,1	0,1	–0,1	0,1
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,5	1,0	–0,5	–0,1	–0,1	0,4	0,4	–1,0	–1,0	–0,2	–0,2
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,5	1,0	–0,5	–0,1	–0,1	0,1	0,6	–1,0	–1,0	–0,2	–0,2
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,5	1,0	–0,5	–0,1	–0,1	0,6	0,1	–1,0	–1,0	–0,2	–0,2
	a_t	f_t	0,1	0,2	–0,1	0,1	–0,1	1,0	–1,0	0,2	–0,2	0,0	0,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	0,7	–0,9	–0,2	–0,2	–0,2	–0,6	–0,2	1,0	1,0	1,0	1,0
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,3	–0,6	–0,1	–0,2	0,1	–0,9	0,9	0,6	0,5	0,3	0,3
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,6	–0,5	0,2	–0,2	0,1	–0,9	0,9	0,5	0,2	0,1	1,0
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	0,7	–0,9	–0,2	–0,2	–0,2	–0,2	–0,6	1,0	1,0	1,0	1,0
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,3	–0,6	–0,1	0,1	–0,2	0,9	–0,9	0,5	0,6	0,3	0,3
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,6	–0,5	0,2	0,1	–0,2	0,9	–0,9	0,2	0,5	1,0	0,1

Table 2.8.18 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Brazil

Max. response			M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case			1 (Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
Global loads	M_{wv}	f_{mv}	1,0	–0,1	–0,5	–0,8	–0,8	–0,1	–0,1	0,7	0,7	0,5	0,5
	$M_{wv\text{-}h}$	f_{mh}	–0,1	–0,1	–0,2	–1,0	1,0	–0,8	0,8	–0,1	0,1	–0,1	0,1
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,1	1,0	–0,3	–0,5	–0,5	0,2	0,2	–0,1	–0,1	–0,5	–0,5
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,1	1,0	–0,3	–0,5	–0,5	–0,1	0,5	–0,1	–0,1	–0,5	–0,5
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,1	1,0	–0,3	–0,5	–0,5	0,5	–0,1	–0,1	–0,1	–0,5	–0,5
	a_t	f_t	0,1	0,1	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	1,0	–0,7	–0,5	–0,9	–0,7	–0,7	0,3	1,0	1,0	1,0	1,0
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,3	–0,4	–0,2	–0,6	0,2	–0,8	0,8	0,4	0,4	0,6	0,6
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,5	–0,3	–0,1	–0,4	0,4	–0,8	0,8	0,5	0,5	1,0	1,0
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	1,0	–0,7	–0,5	–0,7	–0,9	0,3	–0,7	1,0	1,0	1,0	1,0
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,3	–0,4	–0,2	0,2	–0,6	0,8	–0,8	0,4	0,4	0,6	0,6
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,5	–0,3	–0,1	0,4	–0,4	0,8	–0,8	0,5	0,5	1,0	1,0

Table 2.8.19 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, Brazil

Max. response			a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	0,9	–1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–1,0	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,0	0,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	–0,1	0,2
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,2	–0,1
	a_t	f_t	0,0	0,0	0,1	–0,1	0,0	0,0	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9	–0,2	0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–0,9	0,9	0,9	0,9	0,9	1,0	0,8	0,9	–0,7	0,7
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–0,8	0,8	0,9	0,7	0,9	0,9	1,0	1,0	–0,7	0,7
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,9	1,0	0,1	–0,2
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–0,9	0,9	0,9	0,9	1,0	0,9	0,9	0,8	0,7	–0,7
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–0,8	0,8	0,7	0,9	0,9	0,9	1,0	1,0	0,7	–0,7

Table 2.8.20 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, Brazil

Max. response			a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,6	–0,6	–0,1	–0,1
	$M_{wv\text{-}h}$	f_{mh}	–0,1	–0,1	–0,1	0,1	0,0	0,0	–0,1	0,1	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	1,0	–0,9	–0,8	–0,8	–1,0	–1,0	–0,6	–0,6	0,2	0,2
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	1,0	–0,9	–0,8	–0,8	–1,0	–1,0	–0,6	–0,6	–0,1	0,4
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	1,0	–0,9	–0,8	–0,8	–1,0	–1,0	–0,6	–0,6	0,4	–0,1
	a_t	f_t	0,1	0,1	0,1	–0,1	0,1	0,1	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–1,0	0,9	1,0	1,0	1,0	1,0	0,7	0,7	–0,5	0,3
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–0,5	0,4	0,5	0,4	1,0	0,6	0,5	0,5	–0,8	0,8
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–0,4	0,3	0,5	0,4	1,0	0,6	0,1	0,8	–0,8	0,8
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–1,0	0,9	1,0	1,0	1,0	1,0	0,7	0,7	0,3	–0,5
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–0,5	0,4	0,4	0,5	0,6	1,0	0,5	0,5	0,8	–0,8
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–0,4	0,3	0,4	0,5	0,6	1,0	0,8	0,1	0,8	–0,8

Table 2.8.21 **Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, Brazil**

Max. response			P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P
Global loads	M_{wv}	f_{mv}	–0,4	–0,1	–0,1	0,4	0,4	0,2	0,2
	$M_{wv\text{-}h}$	f_{mh}	–0,4	–0,1	0,1	–0,4	0,4	–0,1	0,1
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	–1,0	0,1	0,1	1,0	1,0	0,4	0,4
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	–1,0	0,1	0,1	1,0	1,0	0,2	0,5
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	–1,0	0,1	0,1	1,0	1,0	0,5	0,2
	a_t	f_t	0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	1,0	0,2	0,2	–1,0	–1,0	–0,5	–0,2
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,6	0,2	0,2	–0,6	–0,6	–0,8	0,7
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,5	1,0	1,0	–0,4	–0,3	–0,7	0,7
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	1,0	0,2	0,2	–1,0	–1,0	–0,2	–0,5
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,6	0,2	0,2	–0,6	–0,6	0,7	–0,8
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,3	1,0	1,0	–0,3	–0,4	0,7	–0,7

Table 2.8.22 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, Brazil

Max. response			P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P
Global loads	M_{wv}	f_{mv}	0,2	–0,3	–0,3	–0,2	–0,2	–0,1	–0,1
	$M_{wv\text{-}h}$	f_{mh}	–0,1	–0,1	0,1	–0,2	0,2	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,4	–0,5	–0,5	1,0	1,0	0,2	0,2
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,4	–0,5	–0,5	1,0	1,0	–0,1	0,4
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,4	–0,5	–0,5	1,0	1,0	0,4	–0,1
	a_t	f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–1,0	1,0	1,0	–0,6	–0,7	–0,7	0,4
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–0,5	0,5	0,5	–0,4	–0,4	–0,8	0,8
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–0,7	1,0	1,0	–0,3	–0,1	–0,8	0,8
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–1,0	1,0	1,0	–0,7	–0,6	0,4	–0,7
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–0,5	0,5	0,5	–0,4	–0,4	0,8	–0,8
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–0,7	1,0	1,0	–0,1	–0,3	0,8	–0,8

Table 2.8.23 Dynamic load cases for strength assessment (by FEM) for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response			M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Sagging)	Q_{wv} (Hogging)	a_v		$M_{wv\text{-}h}$ (Hogging)	
Dynamic load case			1	2	3	4	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	–1,0	1,0	–1,0	1,0	0,8	0,8	0,4	0,4
	Q_{wv}	f_{qv}	1,0	–1,0	1,0	–1,0	–0,6	–0,6	–0,2	–0,2
	$M_{wv\text{-}h}$	f_{mh}	0,1	–0,1	–0,1	0,1	–0,1	0,1	–1,0	–1,0
Accelerations	a_v	f_v	–0,4	0,4	–0,4	0,4	1,0	1,0	0,2	0,2
	a_t	f_t	–0,1	0,1	–0,1	0,1	0,1	–0,1	0,1	0,1
	a_{lng}	f_{lng}	0,3	–0,3	0,1	–0,1	–0,4	–0,4	–0,6	–0,6
Dynamic wave pressure for port side	P_{WL}	f_{WL}	–0,4	0,4	–0,5	0,5	–0,1	–0,2	–0,1	0,3
	P_{bilge}	f_{bilge}	–0,2	0,2	–0,2	0,2	–0,5	–0,5	–0,2	0,3
	P_{ctr}	f_{ctr}	–0,4	0,4	–0,4	0,4	–0,8	–0,8	0,2	0,2
Dynamic wave pressure for starboard side	P_{WL}	f_{WL}	–0,4	0,4	–0,5	0,5	–0,2	–0,1	0,3	–0,1
	P_{bilge}	f_{bilge}	–0,2	0,2	–0,2	0,2	–0,5	–0,5	0,3	–0,2
	P_{ctr}	f_{ctr}	–0,4	0,4	–0,4	0,4	–0,8	–0,8	0,2	0,2

Table 2.8.24 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response			M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case			1 (Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
Global loads	M_{wv}	f_{mv}	1,0	0,8	–0,5	–0,4	–0,4	0,2	0,2	–0,5	–0,5	–0,3	–0,3
	$M_{wv\text{-}h}$	f_{mh}	–0,1	–0,1	–0,5	–1,0	1,0	–0,1	0,1	–0,1	0,1	–0,2	0,2
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,4	1,0	–0,3	–0,2	–0,2	0,3	0,3	–1,0	–1,0	–0,1	–0,1
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,4	1,0	–0,3	–0,2	–0,2	0,1	0,4	–1,0	–1,0	–0,1	–0,1
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,4	1,0	–0,3	–0,2	–0,2	0,4	0,1	–1,0	–1,0	–0,1	–0,1
	a_t	f_t	0,1	0,1	0,0	0,1	–0,1	1,0	–1,0	0,3	–0,3	0,0	0,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,3	0,3	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,3	0,4	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,3	0,2	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,3	0,3	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	0,4	–0,8	–0,2	–0,2	–0,2	–0,3	–0,1	1,0	1,0	0,2	0,2
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,2	–0,6	–0,2	–0,3	0,2	–0,8	0,8	0,8	0,7	0,5	0,2
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,4	–0,3	–0,2	–0,3	0,1	–0,7	0,7	0,7	0,3	1,0	1,0
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	0,4	–0,8	–0,2	–0,2	–0,2	–0,1	–0,3	1,0	1,0	0,2	0,2
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,2	–0,6	–0,2	0,2	–0,3	0,8	–0,8	0,7	0,8	0,2	0,5
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,4	–0,3	–0,2	0,1	–0,3	0,7	–0,7	0,3	0,7	1,0	1,0

Table 2.8.25 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response			M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case			1 (Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
Global loads	M_{wv}	f_{mv}	1,0	0,1	–0,5	0,1	0,1	0,1	0,1	0,9	0,9	–0,3	–0,3
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,1	0,0	–1,0	1,0	–0,7	0,7	–0,1	0,1	0,0	0,0
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	0,3	1,0	–0,3	0,3	0,3	0,1	0,1	0,2	0,2	–0,3	–0,3
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	0,3	1,0	–0,3	0,5	0,5	–0,1	0,3	0,2	0,2	–0,3	–0,3
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	0,3	1,0	–0,3	0,1	0,1	0,3	–0,1	0,2	0,2	–0,3	–0,3
	a_t	f_t	0,0	–0,1	0,0	1,0	–1,0	1,0	–1,0	0,0	0,0	0,0	0,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,1	–0,2	1,0	0,0	0,0	0,1	0,1	–0,3	–0,3	0,6	0,6
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,1	–0,2	1,0	–0,1	0,1	0,1	0,1	–0,3	–0,3	0,6	0,6
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,1	–0,2	1,0	0,1	–0,1	0,1	0,1	–0,3	–0,3	0,6	0,6
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,1	–0,2	1,0	0,0	0,0	0,1	0,1	–0,3	–0,3	0,6	0,6
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	0,9	–0,6	–0,4	–0,6	0,3	–0,4	0,2	1,0	1,0	0,3	0,3
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,3	–0,5	–0,2	–1,0	1,0	–0,7	0,7	0,4	0,4	0,5	0,5
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,5	–0,2	0,1	–0,9	0,9	–0,6	0,6	0,6	0,6	1,0	1,0
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	0,9	–0,6	–0,4	0,3	–0,6	0,2	–0,4	1,0	1,0	0,3	0,3
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,3	–0,5	–0,2	1,0	–1,0	0,7	–0,7	0,4	0,4	0,5	0,5
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,5	–0,2	0,1	0,9	–0,9	0,6	–0,6	0,6	0,6	1,0	1,0

Table 2.8.26 **Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)**

Max. response			a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	0,8	–0,8	–0,9	–0,9	–1,0	–1,0	–0,4	–0,4	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	–0,1	–0,1	–0,1	0,1	–0,1	0,1	–0,3	0,3	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,1	–0,1	0,0	0,0
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,1	–0,1	–0,1	–0,1
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,1	–0,1	0,1	0,1
	a_t	f_t	0,1	0,1	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,3	0,3	–0,1	0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–1,0	0,9	1,0	0,7	1,0	1,0	0,3	0,3	–0,5	0,5
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–0,4	0,4	0,3	0,5	0,5	0,6	1,0	0,6	–0,5	0,4
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,3	0,3	0,1	–0,1
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–1,0	0,9	0,7	1,0	1,0	1,0	0,3	0,3	0,5	–0,5
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–0,4	0,4	0,5	0,3	0,6	0,5	0,6	1,0	0,4	–0,5

Table 2.8.27 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response			a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case			1	2	3S	3P	4S	4P	5S	5P	6S	6P
Global loads	M_{wv}	f_{mv}	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–1,0	–1,0	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	0,1	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	1,0	–0,8	–0,8	–0,8	–1,0	–1,0	–0,5	–0,5	0,1	0,1
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	1,0	–0,8	–0,8	–0,8	–1,0	–1,0	–0,5	–0,5	0,2	0,2
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	1,0	–0,8	–0,8	–0,8	–1,0	–1,0	–0,5	–0,5	–0,1	–0,1
	a_t	f_t	–0,1	0,0	0,0	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	–1,0	0,8	1,0	1,0	1,0	1,0	1,0	1,0	–0,2	0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	–0,7	0,6	0,7	0,7	1,0	0,9	0,8	0,7	–0,7	0,6
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	–0,4	0,4	0,6	0,6	0,9	0,8	1,0	0,8	–0,6	0,6
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	–1,0	0,8	1,0	1,0	1,0	1,0	1,0	1,0	0,1	–0,2
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	–0,7	0,6	0,7	0,7	0,9	1,0	0,7	0,8	0,6	–0,7
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	–0,4	0,4	0,6	0,6	0,8	0,9	0,8	1,0	0,6	–0,6

Table 2.8.28 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response			P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P
Global loads	M_{wv}	f_{mv}	1,0	–0,3	–0,3	0,5	0,5	0,2	0,2
	M_{wv-h}	f_{mh}	–0,1	–0,9	0,9	–0,5	0,5	0,0	0,0
Accelerations	a_{v-mid}	f_{v-mid}	0,4	–0,2	–0,2	1,0	1,0	0,3	0,3
	a_{v-pt}	f_{v-pt}	0,4	–0,2	–0,2	1,0	1,0	0,2	0,4
	a_{v-stb}	f_{v-stb}	0,4	–0,2	–0,2	1,0	1,0	0,4	0,2
	a_t	f_t	–0,1	0,0	0,0	0,1	–0,1	1,0	–1,0
	$a_{lng-mid}$	$f_{lng-mid}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
	a_{lng-pt}	f_{lng-pt}	0,1	0,2	0,2	0,7	0,7	0,1	0,1
	$a_{lng-stb}$	$f_{lng-stb}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
	$a_{lng-ctr}$	$f_{lng-ctr}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr-STB}$	$f_{ctr-STB}$	–0,1	0,6	0,6	–0,9	–0,9	–0,4	–0,2
	$P_{bilge-STB}$	$f_{bilge-STB}$	–0,1	0,6	0,3	–0,7	–0,7	–0,6	0,5
	P_{WL-STB}	f_{WL-STB}	–0,2	1,0	0,9	–0,5	–0,2	–0,5	0,5
Dynamic wave pressure for port side	P_{ctr-PS}	f_{ctr-PS}	–0,1	0,6	0,6	–0,9	–0,9	–0,2	–0,4
	$P_{bilge-PS}$	$f_{bilge-PS}$	–0,1	0,3	0,6	–0,7	–0,7	0,5	–0,6
	P_{WL-PS}	f_{WL-PS}	–0,2	0,9	1,0	–0,2	–0,5	0,5	–0,5

Table 2.8.29 **Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)**

Max. response			P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case			1	2S	2P	3S	3P	4S	4P
Global loads	M_{wv}	f_{mv}	–1,0	0,1	0,1	0,8	0,8	0,1	0,1
	$M_{wv\text{-}h}$	f_{mh}	0,0	0,0	0,0	–0,1	0,1	–0,8	0,8
Accelerations	$a_{v\text{-}mid}$	$f_{v\text{-}mid}$	–0,7	–0,4	–0,4	1,0	1,0	0,2	0,2
	$a_{v\text{-}pt}$	$f_{v\text{-}pt}$	–0,7	–0,4	–0,4	1,0	1,0	0,3	0,3
	$a_{v\text{-}stb}$	$f_{v\text{-}stb}$	–0,7	–0,4	–0,4	1,0	1,0	0,1	0,1
	a_t	f_t	0,1	0,0	0,0	0,1	–0,1	1,0	–1,0
	$a_{lng\text{-}mid}$	$f_{lng\text{-}mid}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
	$a_{lng\text{-}pt}$	$f_{lng\text{-}pt}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
	$a_{lng\text{-}stb}$	$f_{lng\text{-}stb}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
	$a_{lng\text{-}ctr}$	$f_{lng\text{-}ctr}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
Dynamic wave pressure for starboard side	$P_{ctr\text{-}STB}$	$f_{ctr\text{-}STB}$	1,0	0,4	0,4	–0,9	–0,9	–0,5	0,1
	$P_{bilge\text{-}STB}$	$f_{bilge\text{-}STB}$	0,3	0,5	0,5	–0,2	–0,2	–0,7	0,6
	$P_{WL\text{-}STB}$	$f_{WL\text{-}STB}$	0,2	1,0	1,0	–0,1	–0,1	–0,7	0,7
Dynamic wave pressure for port side	$P_{ctr\text{-}PS}$	$f_{ctr\text{-}PS}$	1,0	0,4	0,4	–0,9	–0,9	0,1	–0,5
	$P_{bilge\text{-}PS}$	$f_{bilge\text{-}PS}$	0,3	0,5	0,5	–0,2	–0,2	0,6	–0,7
	$P_{WL\text{-}PS}$	$f_{WL\text{-}PS}$	0,2	1,0	1,0	–0,1	–0,1	0,7	–0,7

Section

1 **Scantling requirements**

2 **Cargo tank region**

3 **Forward of the forward cargo tank**

4 **Machinery space**

5 **Aft end**

6 **Evaluation of structure for sloshing and impact loads**

7 **Application of scantling requirements to other structure**

Section 1
Scantling requirements

1.1 Symbols

1.1.1 The. symbols used in this Chapter are defined as follows:

L = Rule length, in metres, as defined in Pt 4, Ch 1,5
B = moulded breadth, in metres, as defined in Pt 4, Ch 1,5
D = moulded depth, as defined in Pt 4, Ch 1,5
C_{wv} = wave coefficient, as defined in Ch 2,3.1
C_b = block coefficient, as defined in Pt 4 Ch 1,5, but is not to be taken as less than 0,7
ρ = density, tonnes/m^3, not to be taken less than specified values defined in Table 2.1.1 in Chapter 2
g = acceleration due to gravity, 9,81 m/s^2
k = higher strength steel factor, as defined in Ch 1,3.1.7
f_{FOI} = FOI design safety factor, defined in 5.8.4 in *ShipRight*-FOI procedure.

1.2 Loading guidance

1.2.1.1 All units are to be provided with loading guidance information containing sufficient information to enable the loading, unloading and ballasting operations and inspection/maintenance of the unit within the stipulated operational limitations. The loading guidance information is to include an approved Loading Manual and Loading Computer System complying with the requirements given in Pt 3, Ch 4,8 of the Rules for Ships.

1.2.1.2 All relevant loading conditions and limitations are to be clearly stated in the loading manual. The loading computer system should be installed to monitor still water bending moments and shear forces and ensure they are maintained within the approved permissible levels.

1.3 Hull girder bending strength

1.3.1 **General.**

1.3.1.1 The hull girder section modulus requirements in 1.3.3 apply along the full length of the hull girder, from AP to FP.

1.3.1.2 Structural members included in the hull girder section modulus are to satisfy the buckling criteria given in 1.5.

1.3.2 **Minimum requirements.**

1.3.2.1 In order to limit the maximum permissible deflection, the hull midship section net moment of inertia about the transverse neutral axis is not to be less than the following:

$$I_{v\text{-min}} = 2{,}7 C_{wv} L^3 B (C_b + 0{,}7)\, 10^{-8} \quad \text{m}^4$$

1.3.3 Hull girder requirement on total design bending moment.

1.3.3.1 The net vertical hull girder section modulus requirement as defined in 1.3.3.2 is to be assessed for both hogging and sagging conditions.

1.3.3.2 The hull midship section net modulus about the transverse neutral axis is not to be less than the Rule required section modulus, based on the permissible still water and design wave bending moments as follows:

$$Z_{\text{v-req}} = \frac{|M_{\text{sw-perm}} + M_{\text{wv-v}}|}{\sigma_{\text{perm}}} \, 10^{-3} \quad \text{m}^3$$

where

$M_{\text{sw-perm}}$ = permissible hull girder hogging or sagging still water bending moment, in kNm, as given in Table 3.1.1

$M_{\text{wv-v}}$ = hogging or sagging vertical wave bending moment, in kNm, as given in Table 3.1.1

σ_{perm} = permissible hull girder bending stress as given in Table 3.1.1, in N/mm^2.

Table 3.1.1 Loads and corresponding acceptance criteria for hull girder bending assessment

Design load combination	Still water bending moment, $M_{\text{sw-perm}}$	Vertical wave bending moment, $M_{\text{wv-v}}$	Permissible hull girder bending stress, σ_{perm} (1)	
(S)	$M_{\text{sw-perm}}$	0	$143/(f_{\text{FOI}}\,k)$	within 0,4*L* amidships
			$105/(f_{\text{FOI}}\,k)$	at and forward of 0,9*L* from AP and at and aft of 0,1*L* from AP
(S + D)	$M_{\text{sw-perm}}$	$M_{\text{wv-v}}$	$190/(f_{\text{FOI}}\,k)$	within 0,4*L* amidships
			$140/(f_{\text{FOI}}\,k)$	at and forward of 0,9*L* from AP and at and aft of 0,1*L* from AP

Symbols

$M_{\text{sw-perm}}$ = permissible hull girder hogging and sagging still water bending moment for Static (S) or Static + Dynamic (S+D) design load combination, as applicable from Table 2.6.1 in Chapter 2, for the load case under consideration, in kNm

$M_{\text{wv-v}}$ = hogging and sagging vertical wave bending moments, in kNm, as defined in Ch 2,3.7.1.1

$M_{\text{wv-v}}$ is to be taken as:

$M_{\text{wv-hog}}$ for assessment with respect to hogging vertical wave bending moment

$M_{\text{wv-sag}}$ for assessment with respect to sagging vertical wave bending moment

NOTE

σ_{perm} is to be linearly interpolated between values given.

1.4 Hull girder shear strength

1.4.1 General.

1.4.1.1 The hull girder shear strength requirements apply along the full length of the hull girder, from AP to FP.

1.4.1.2 The following requirements are applicable to units with standard structural arrangements as shown in Fig. 3.1.1. Alternative configurations will be specially considered.

1.4.2 Assessment of hull girder shear strength.

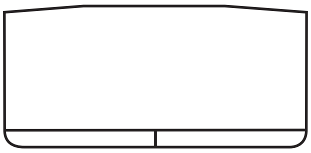
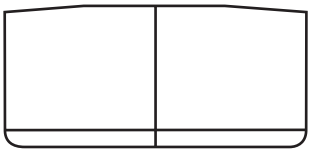
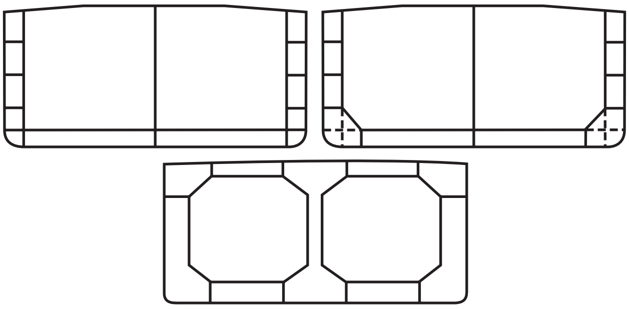
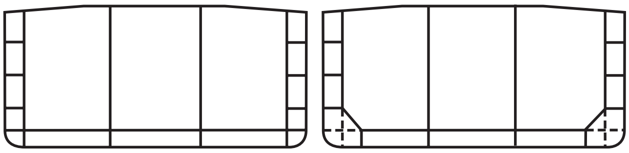
1.4.2.1 The net hull girder shear strength capacity, $Q_{\text{v-net50}}$, is not to be less than the required vertical shear force, $Q_{\text{v-req}}$:

$$Q_{\text{v-req}} = Q_{\text{sw-perm}} + Q_{\text{wv}} \quad \text{KN}$$

where

$Q_{\text{sw-perm}}$ = permissible hull girder positive or negative still water shear force as given in Table 3.1.2, in kN

Q_{wv} = vertical wave positive or negative shear force as defined in Table 3.1.2, in kN.

Hull configuration	f_i factors
Outside cargo region (no longitudinal bulkhead) 	Side shell $f_1 = 0,5$
Outside cargo region (centreline bulkhead) 	Side shell $f_1 = 0,231 + 0,076 \dfrac{A_{1\text{-net50}}}{A_{3\text{-net50}}}$ Longitudinal bulkhead $f_3 = 0,538 - 0,152 \dfrac{A_{1\text{-net50}}}{A_{3\text{-net50}}}$
One centreline bulkhead 	Side shell $f_1 = 0,055 + 0,097 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} + 0,020 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$ Inner hull $f_2 = 0,193 - 0,059 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} + 0,058 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$ Longitudinal bulkhead $f_3 = 0,504 - 0,076 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} - 0,156 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$
Two longitudinal bulkheads 	Side shell $f_1 = 0,028 + 0,087 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} + 0,023 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$ Inner hull $f_2 = 0,119 - 0,038 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} + 0,072 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$ Longitudinal bulkhead $f_3 = 0,353 - 0,049 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} - 0,095 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$

Symbols

i = index for the structural member under consideration
  1, for the side shell
  2, for the inner hull
  3, for the longitudinal bulkhead
$A_{\text{i-net50}}$ = net area based on deduction $0,5t_{\text{corr}}$, of the structural member, i, at one side of the section under consideration. The area $A_{3\text{-net50}}$ for the centreline bulkhead is not to be reduced for symmetry around the centreline.

NOTES

1. The effective net hull girder vertical shear area includes the net plating area of the side shell including the bilge, the inner hull including the hopper side and the outboard girder under, the upper deck girder where applicable, and the longitudinal bulkheads including the double bottom girders in line.
2. For longitudinal strength members forming the web of the hull girder which are inclined to the vertical, the area of the member to be included in the shear force calculation is to be based on the projected area onto the vertical plane.

Fig. 3.1.1 Shear force distribution factors

Table 3.1.2 Loads and corresponding acceptance criteria for hull girder shear assessment

Design load combination	Still water shear force, $Q_{sw\text{-}perm}$	Vertical wave shear force, Q_{wv}	Permissible shear stress, τ_{perm}
(S)	$Q_{sw\text{-}perm}$	0	$105/(f_{FOI}\,k)$ for plate ij
(S + D)	$Q_{sw\text{-}perm}$	Q_{wv}	$120/(f_{FOI}\,k)$ for plate ij

Symbols

$Q_{sw\text{-}perm}$ = permissible positive or negative hull girder still water shear force for Static (S) or Static + Dynamic (S + D) design load combination, as applicable from Table 2.6.1 in Chapter 2 for the load case under consideration, in kN
Q_{wv} = positive or negative vertical wave shear, in kN, as defined in Ch 2,3.7.2.1. Q_{vw} is to be taken as:
$Q_{wv\text{-}pos}$ for assessment with respect to maximum positive permissible still water shear force
$Q_{wv\text{-}neg}$ for assessment with respect to minimum negative permissible still water shear force
plate ij = for each plate j, index i denotes the structural member of which the plate forms a component

1.4.2.2 The permissible positive and negative still water shear forces, $Q_{sw\text{-}perm}$ are to satisfy the following for each loading condition:

$Q_{sw-perm} \leq Q_{v-net50} - Q_{wv-pos}$ kN

for maximum permissible positive shear force

$Q_{sw\text{-}perm} \geq -\,Q_{v-net50} - Q_{wv-neg}$ kN

for minimum permissible negative shear force

where

$Q_{v\text{-}net50}$ = net hull girder vertical shear strength to be taken as the minimum for all plate elements that contribute to the hull girder shear capacity

$$= \frac{\tau_{ij-perm}\, t_{ij-net50}}{1000 q_v} \quad \text{kN}$$

$\tau_{ij-perm}$ = permissible hull girder shear stress, τ_{perm}, as given in Table 3.1.2, in N/mm^2, for plate ij
$Q_{wv\text{-}pos}$ = positive vertical wave shear force, in kN, as defined in Table 3.1.2
$Q_{wv\text{-}neg}$ = negative vertical wave shear force, in kN, as defined in Table 3.1.2
$t_{ij-net50}$ = equivalent net thickness, t_{net50}, for plate ij, in mm. For longitudinal bulkheads between cargo tanks, t_{net50} is to be taken as $t_{sfc\text{-}net50}$ and $t_{str\text{-}k}$ as appropriate, *see* 1.4.3.1 and 1.4.4.1
t_{net50} = net thickness of plate, in mm
= $t_{grs} - 0{,}5 t_{corr}$
t_{grs} = gross plate thickness, in mm. For corrugated bulkheads, to be taken as the minimum of $t_{w\text{-}grs}$ and $t_{f\text{-}grs}$, in mm
$t_{w\text{-}grs}$ = gross thickness of the corrugation web, in mm
$t_{f\text{-}grs}$ = gross thickness of the corrugation flange, in mm
t_{corr} = corrosion addition, in mm, as defined in Ch 1,12
q_v = unit shear flow per mm for the plate being considered and based on the net scantlings. Where direct calcultion of the unit shear flow is not available, the unit shear flow may be taken equal to

$$= f_i \left(\frac{q_{1\text{-}net50}}{I_{v\text{-}net50}}\right) 10^{-9} \quad \text{mm}^{-1}$$

f_i = shear force distribution factor for the main longitudinal hull girder shear carrying members being considered. For standard structural configurations f_i is as defined in Fig. 3.1.1
$q_{1\text{-}net50}$ = first moment of area, in cm^2, about the horizontal neutral axis of the effective longitudinal members between the vertical level at which the shear stress is being determined and the vertical extremity, taken at the section being considered. The first moment of area is to be based on the net thickness, t_{net50}
$I_{v\text{-}net50}$ = net vertical hull girder section moment of inertia, in m^4.

1.4.3 Shear force correction for longitudinal bulkheads between cargo tanks.

1.4.3.1 For longitudinal bulkheads between cargo tanks, the effective net plating thickness of the plating above the inner bottom, $t_{sfc\text{-}net50}$ for plate ij, used for calculation of hull girder shear strength, $Q_{v\text{-}net50}$, may be corrected for local shear distribution and is given by:

$t_{sfc\text{-}net50} = t_{grs} - 0{,}5 t_{corr} - t_{\Delta}$ mm

where

t_{grs} = gross plate thickness, in mm
t_{corr} = corrosion addition, in mm, as defined in Ch 1,12
t_{Δ} = thickness deduction for plate ij, in mm, as defined in 1.4.3.2

1.4.3.2 The vertical distribution of thickness reduction for shear force correction is assumed to be triangular, as indicated in Fig. 3.1.2. The thickness deduction, t_Δ, to account for shear force correction is to be taken as:

$$t_\Delta = \frac{\delta Q_3}{h_{blk}\,\tau_{ij\text{-}perm}}\left(1 - \frac{x_{blk}}{0{,}5 l_{tk}}\right)\left(2 - \frac{2\,(z_p - h_{db})}{h_{blk}}\right) \text{ mm}$$

where

δ_{Q3} = shear force correction for longitudinal bulkhead as defined in 1.4.3.3 and 1.4.3.5 for ships with one or two longitudinal bulkheads respectively, in kN

l_{tk} = length of cargo tank, in metres

h_{blk} = height of longitudinal bulkhead, in metres, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in Fig. 3.1.2

x_{blk} = the minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead, in metres. To be taken positive and not greater than $0{,}5 l_{tk}$

z_p = the vertical distance from the lower edge of plate ij to the base line, in metres. Not to be taken as less than h_{db}

h_{db} = height of double bottom, in m, as shown in Fig. 3.1.2

$\tau_{ij\text{-}perm}$ = permissible hull girder shear stress, τ_{perm}, in N/mm^2 for plate ij
= $120/k_{ij}$

k_{ij} = higher strength steel factor, k, for plate ij as defined in 1.1.

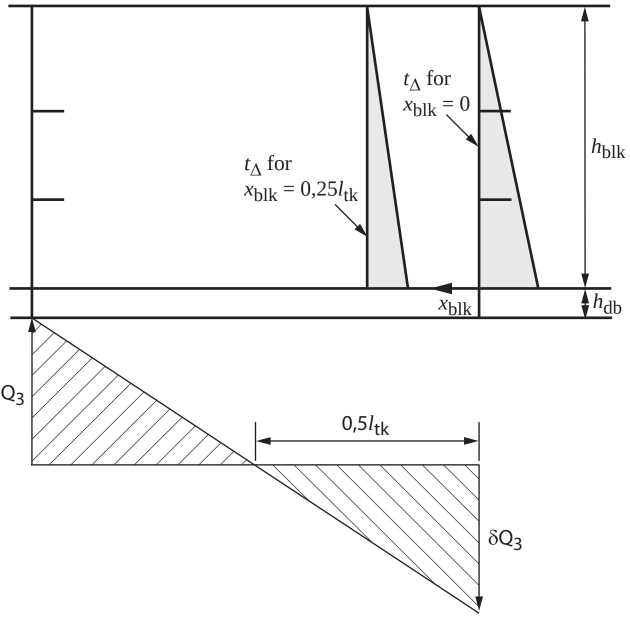

t_Δ for $x_{blk} = 0$
t_Δ for $x_{blk} = 0{,}25 l_{tk}$
h_{blk}
x_{blk}
h_{db}
δQ_3
$0{,}5 l_{tk}$
δQ_3

Fig. 3.1.2 Shear force correction for longitudinal bulkheads

1.4.3.3 For ships with a centreline bulkhead between the cargo tanks, the shear force correction in way of transverse bulkhead, δ_{Q3}, is to be taken as:

$\delta_{Q3} = 0{,}5 K_3 F_{db}$ kN

where

K_3 = correction factor, as defined in 1.4.3.4

F_{db} = maximum resulting force on the double bottom in a tank, in kN, as defined in 1.4.3.7.

1.4.3.4 For ships with a centreline bulkhead between the cargo tanks, the correction factor, K_3, in way of transverse bulkheads is to be taken as:

$$K_3 = \left[0{,}40\left(1 - \frac{1}{1+n}\right) - f_3\right]$$

where

n = number of floors between transverse bulkheads

f_3 = shear force distribution factor, *see* Fig. 3.1.1.

1.4.3.5 For ships with two longitudinal bulkheads between the cargo tanks, the shear force correction, δ_{Q3}, is to be taken as:

$$\delta_{Q3} = 0{,}5 K_3 F_{db} \quad \text{kN}$$

where

K_3 = correction factor, as defined in 1.4.3.6
F_{db} = maximum resulting force on the double bottom in a tank, in kN, as defined in 1.4.3.7.

1.4.3.6 For ships with two longitudinal bulkheads between the cargo tanks, the correction factor, K_3, in way of transverse bulkhead is to be taken as:

$$K_3 = \left[0{,}5\left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3\right]$$

where

n = number of floors between transverse bulkheads
r = ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side and is given by

$$r = \frac{1}{\left[\dfrac{A_{3\text{-net50}}}{A_{1\text{-net50}} + A_{2\text{-net50}}} + \dfrac{2 \times 10^4\, b_{80}\, (n_s + 1)\, A_{3\text{-net50}}}{l_{tk}\, (n_s\, A_{T\text{-net50}} + R)}\right]}$$

Note
For preliminary calculations, r may be taken as 0,5

l_{tk} = length of cargo tank, between transverse bulkheads in the side cargo tank, in metres
b_{80} = 80 per cent of the distance from longitudinal bulkhead to the inner hull longitudinal bulkhead, in metres, at tank mid length
$A_{T\text{-net50}}$ = net shear area of the transverse wash bulkhead, including the double bottom floor directly below, in the side cargo tank, in cm^2, taken as the smallest area in a vertical section. $A_{T\text{-net50}}$ is to be calculated with net thickness given by $t_{grs} - 0{,}5 t_{corr}$
$A_{1\text{-net50}}$ = net area, as shown in Fig. 3.1.1, in m^2
$A_{2\text{-net50}}$ = net area, as shown in Fig. 3.1.1, in m^2
$A_{3\text{-net50}}$ = net area, as shown in Fig. 3.1.1, in m^2
f_3 = shear force distribution factor, as shown in Fig. 3.1.1
n_s = number of wash bulkheads in the side cargo tank
R = total efficiency of the transverse primary support members in the side tank

$$R = \left(\frac{n - n_s}{2} - 1\right)\frac{A_{Q\text{-net50}}}{\gamma} \quad \text{cm}^2$$

$$\gamma = 1 + \frac{300\, b_{80}^2\, A_{Q\text{-net50}}}{I_{psm\text{-net50}}}$$

$A_{Q\text{-net50}}$ = net shear area, in cm^2, of a transverse primary support member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs
$A_{Q\text{-net50}}$ is to be calculated using the net thickness given by $t_{grs - 0,5tcorr}$. The net shear area is to be calculated at the midspan of the members
$I_{psm-net50}$ = net moment of inertia for primary support members, in cm^4, of a transverse primary support member in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. It is to be calculated using the net thickness given by $t_{grs - 0,5tcorr}$. The net moment of inertia is to be calculated at the midspan of the member, including an attached plate width equal to the primary support member spacing
t_{grs} = gross plate thickness, in mm
t_{corr} = corrosion addition, in mm, as defined in Ch 1,12.

1.4.3.7 The maximum resulting force on the double bottom in a tank, F_{db}, is to be taken as:

$$F_{db} = g\, |W_{CT} + W_{CWBT} - \rho_{sw}\, b_2\, l_{tk}\, T_{mean}| \quad \text{kN}$$

where

W_{CT} = weight of cargo, in tonnes, as defined in Table 3.1.3
W_{CWBT} = weight of ballast, in tonnes, as defined in Table 3.1.3
b_2 = breadth, in metres, as defined in Table 3.1.3
l_{tk} = length of cargo tank, between watertight transverse bulkheads in the wing cargo tank, in metres
T_{mean} = draught at the mid length of the tank for the loading condition considered, in metres.

1.4.3.8 The maximum resulting force on the double bottom in a tank, F_{db}, is in no case to be less than that given by the Rule minimum conditions given in Table 3.1.4. Where other tank configurations are proposed, the equivalent loading scenario is to be considered.

Table 3.1.3 Design conditions for double bottoms

Structural configuration	W_{CT}	W_{CWBT}	b_2
Ships with one longitudinal bulkhead	Weight of cargo in cargo tanks, in tonnes, using a minimum specific gravity of 1,025 tonnes/m^3	Weight of ballast between port and starboard inner sides, in tonnes	Maximum breadth between port and starboard inner sides at mid length of tank, in metres, as shown in Fig. 3.1.3
Ships with two longitudinal bulkheads	Weight of cargo in the centre tank, in tonnes, using a minimum specific gravity of 1,025 tonnes/m^3	Weight of ballast below the centre cargo tank, in tonnes	Maximum breadth of the centre cargo tank at mid length of tank, in metres, as shown in Fig. 3.1.3

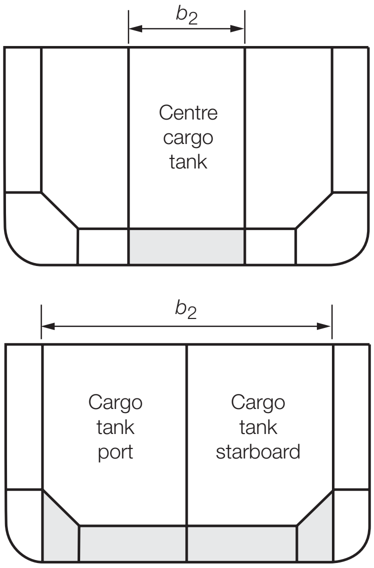


Fig. 3.1.3 Tank breadth to be included for standard tank configuration

Table 3.1.4 Rule minimum conditions for double bottoms

Structural configuration	Positive/negative force, F_{db}	Minimum condition
Ships with one longitudinal bulkhead	Max. positive net vertical force, F_{db} +	0,9T_{SC} and empty cargo and ballast tanks
	Max. negative net vertical force, F_{db} –	0,6T_{SC} and full cargo tanks and empty ballast tanks
Ships with two longitudinal bulkheads	Min. positive net vertical force, F_{db} +	0,9T_{SC} and empty cargo and ballast tanks
	Min. negative net vertical force, F_{db} –	0,6T_{SC} and full centre cargo tank and empty ballast tanks

1.4.4 Shear force correction due to loads from transverse bulkhead stringers.

1.4.4.1 In way of transverse bulkhead stringer connections, within areas as specified in Fig. 3.1.6, the equivalent net thickness of plate used for calculation of the hull girder shear strength, $t_{str\text{-}k}$, where the index k refers to the identification number of the stringer, is not to be taken greater than:

$$t_{str-k} = t_{sfc\text{-}net50}\left(1 - \frac{\tau_{str}}{\tau_{ij\text{-}perm}}\right) \text{ mm}$$

where

$t_{sfc\text{-}net50}$ = effective net plating thickness, in mm, as defined in 1.4.3.1 and calculated at the transverse bulkhead for the height corresponding to the level of the stringer
$\tau_{ij\text{-}perm}$ = permissible hull girder shear stress, τ_{perm}, for plate ij
= $120/k_{ij}$ N/mm^2
k_{ij} = higher strength steel factor, k, for plate ij, as defined in 1.1

$$\tau_{str} = \frac{Q_{str\text{-}k}}{l_{str}\, t_{sfc\text{-}net50}} \quad \text{N/mm}^2$$

l_{str} = connection length of stringer, in metres, *see* Fig. 3.1.4
$Q_{str\text{-}k}$ = shear force on the longitudinal bulkhead from the stringer in loaded condition with tanks abreast full

$$= 0{,}8F_{str\text{–}k}\left(1 - \frac{z_{str} - h_{db}}{h_{bhd}}\right) \quad \text{kN}$$

$F_{str\text{-}k}$ = total stringer supporting force, in kN, as defined in 1.4.4.2
h_{db} = the double bottom height, in metres, as shown in Fig. 3.1.5
h_{blk} = height of bulkhead, in metres, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in Fig. 3.1.5
z_{str} = the vertical distance from baseline to the considered stringer, in metres.

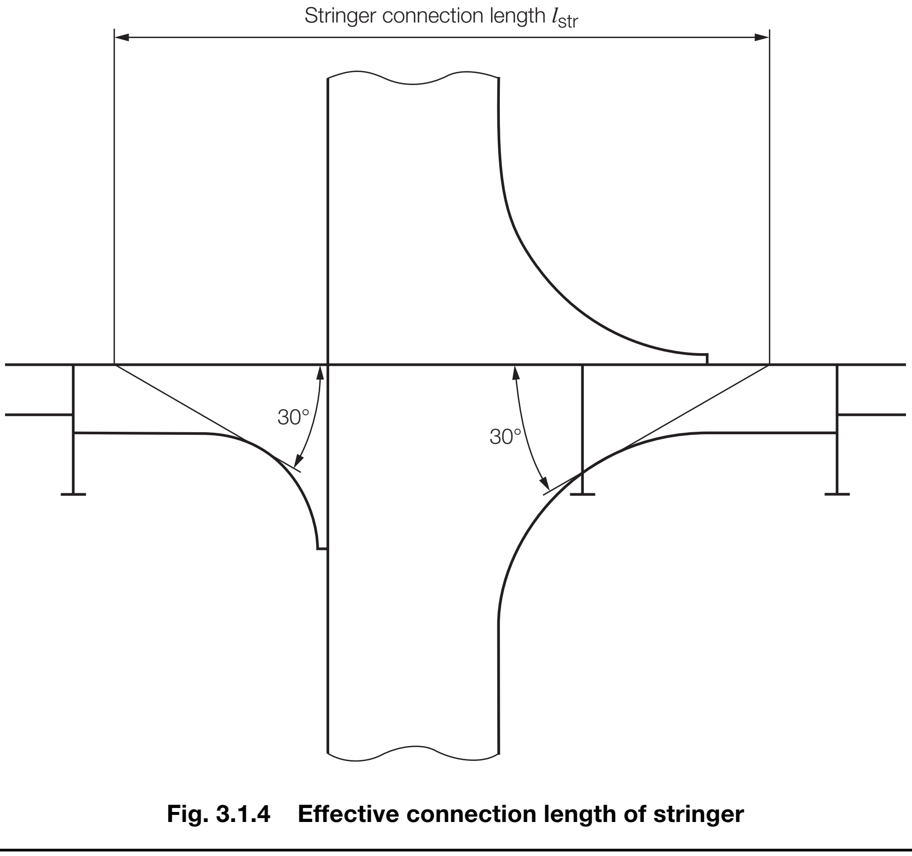


Fig. 3.1.4 Effective connection length of stringer

1.4.4.2 The total stringer supporting force, $F_{str\text{-}k}$, in way of a longitudinal bulkhead is to be taken as:

$$F_{str\text{-}k} = \frac{P_{str}\, b_{str}\, (h_k + h_{k-1})}{2} \quad \text{kN}$$

where
P_{str} = pressure on stringer, in kN/m^2, to be taken as $10h_{tt}$
h_{tt} = the height from the top of the tank to the midpoint of the load area between $h_k/2$ below the stringer and $h_{k\text{-}1}/2$ above the stringer, in metres
h_k = the vertical distance from the considered stringer to the stringer below. For the lowermost stringer, it is to be taken as 80 per cent of the average vertical distance to the inner bottom, in metres

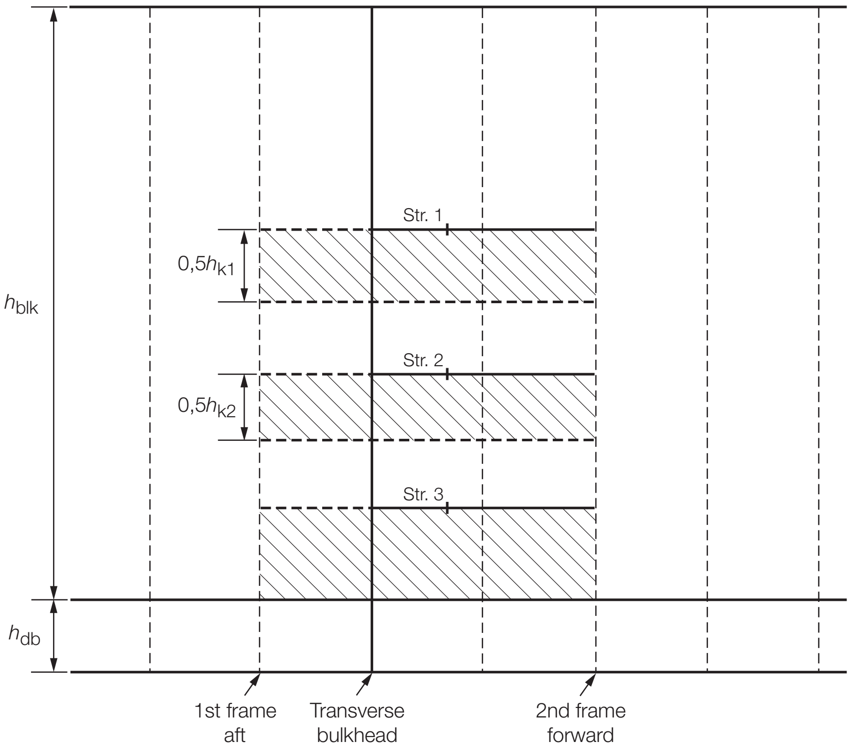


Fig. 3.1.5 Region for stringer correction, t_{ij}, for a unit with three stringers

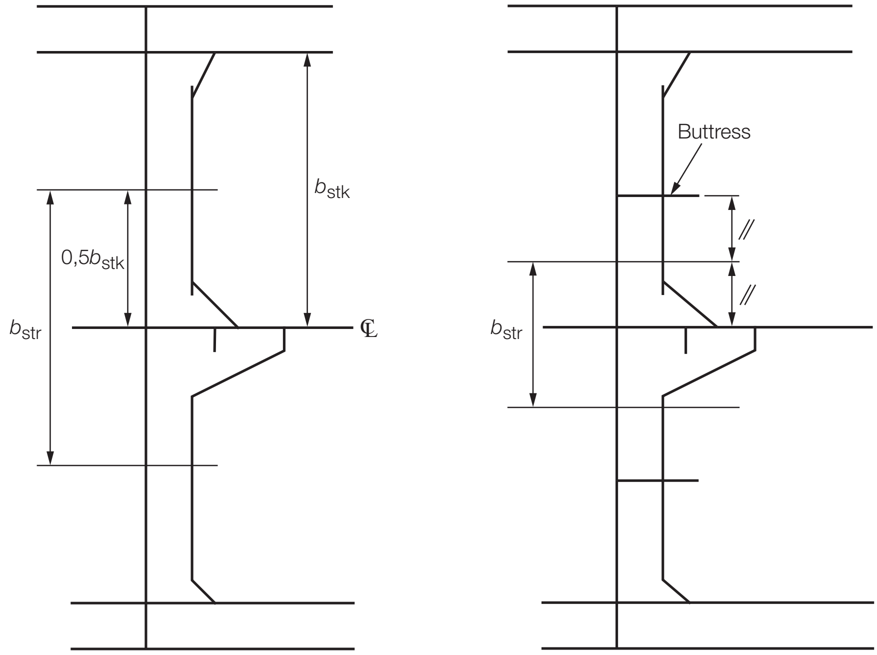
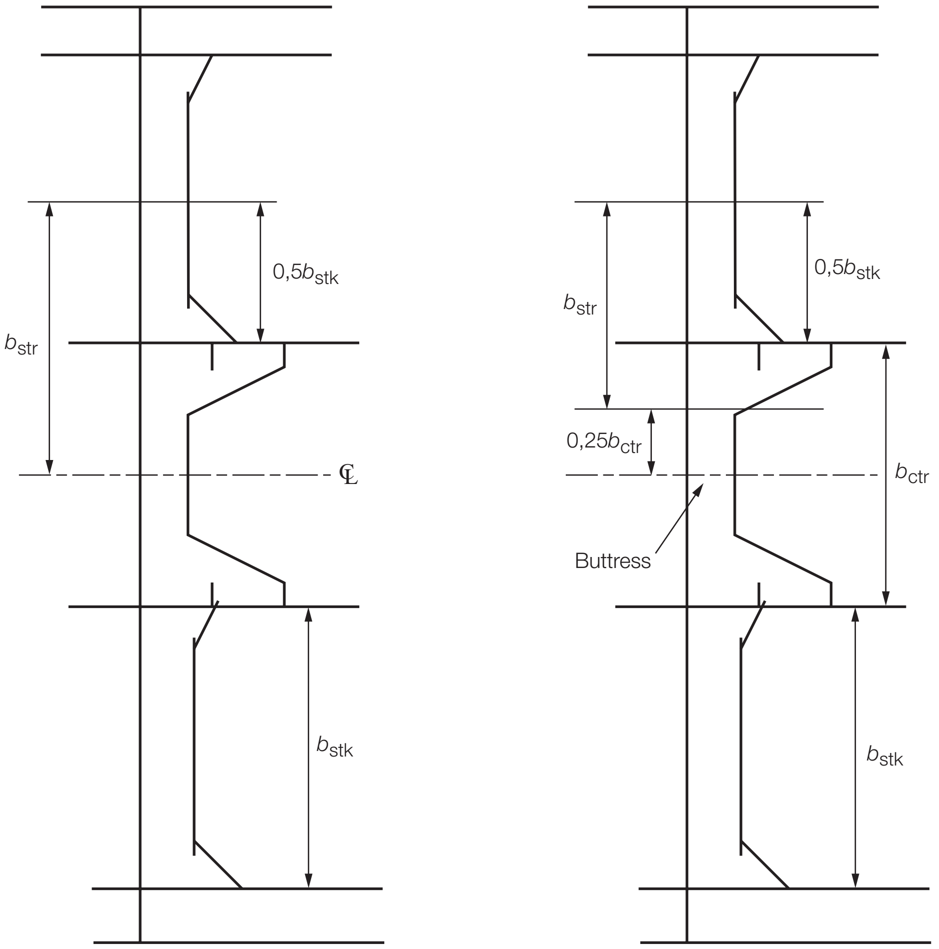


Fig. 3.1.6 Load breadth of stringers for units with a centreline bulkhead

h_{k-1} = the vertical distance from the considered stringer to the stringer above. For the uppermost stringer, it is to be taken as 80 per cent of the average vertical distance to the upper deck, in metres

b_{str} = load breadth acting on the stringer, in metres, *see* Fig. 3.1.6 and Fig. 3.1.7.



NOTES
1. b_{stk} is the breadth of wing cargo tank, in metres.
2. b_{ctr} is the breadth of centre cargo tank, in metres.

Fig. 3.1.7 Load breadth of stringers for units with two inner longitudinal bulkheads

1.4.4.3 Where reinforcement is provided to meet the above requirement, the reinforced area based on $t_{str\text{-}k}$ is to extend longitudinally for the full length of the stringer connection and a minimum of one frame spacing forward and aft of the bulkhead. The reinforced area shall extend vertically from above the stringer level and down to 0,5h_k below the stringer, where h_k, the vertical distance from the considered stringer to the stringer below, is as defined in 1.4.4.2. For the lowermost stringer, the plate thickness requirement $t_{str\text{-}k}$ is to extend down to the inner bottom, *see* Fig. 3.1.6.

1.5 Hull girder buckling strength

1.5.1 General.

1.5.1.1 These requirements apply to plate panels and longitudinals subject to hull girder compression and shear stresses. These stresses are to be based on the permissible values for wave bending moments and shear forces given in Ch 2,2.2 and 3.7.

1.5.1.2 The hull girder buckling strength requirements apply along the full length of the ship, from AP to FP.

1.5.1.3 For the purposes of assessing the hull girder buckling strength in this sub-Section, the following are to be considered separately:

(a) Axial hull girder compressive stress to satisfy requirements in 1.5.2.6 and 1.5.2.8.
(b) Hull girder shear stress to satisfy requirements in 1.5.2.7.

1.5.2 **Buckling assessment.**

1.5.2.1 The buckling assessment of plate panels and longitudinals is to be determined according to Ch 1,18, with hull girder stresses calculated on net hull girder sectional properties.

1.5.2.2 The buckling strength for the buckling assessment is to be derived using local net scantlings, t_{net}, as follows:

t_{net} = $t_{grs} - 1{,}0t_{corr}$ mm

where

t_{grs} = gross plate thickness, in mm
t_{corr} = corrosion addition, in mm, as defined in Ch 1,12.

1.5.2.3 The hull girder compressive stress due to bending, $\sigma_{hg\text{-}net50}$, for the buckling assessment is to be calculated using net hull girder sectional properties and is to be taken as the greater of the following:

$$\sigma_{hg\text{-}net50} = \left| \frac{(z - z_{NA\text{-}net50})\,(M_{sw\text{-}perm} + M_{wv\text{-}v})}{I_{v\text{-}net50}} \right| 10^{-3} \quad \text{N/mm}^2$$

$$\sigma_{hg\text{-}net50} = \frac{30}{k} \quad \text{N/mm}^2$$

where

$M_{sw\text{-}perm}$ = permissible still water bending moment for the Static + Dynamic (S+D) design load combination, as applicable from Table 2.6.1 for the load case under consideration, in kNm, with signs as given in Ch 2,1.2.2.4
$M_{wv\text{-}v}$ = hogging and sagging vertical wave bending moments, in kNm, as defined in Chapter 2, with signs as given in Ch 2,1.2.2.4
$M_{wv\text{-}v}$ is to be taken as:
$M_{wv\text{-}hog}$ for assessment with the hogging still water bending moment
$M_{wv\text{-}sag}$ for assessment with the sagging still water bending moment
z = distance from the structural member under consideration to the baseline, in metres
$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres
$I_{v\text{-}net50}$ = net vertical hull girder section moment of inertia, in m^4.

1.5.2.4 The sagging bending moment values of $M_{sw\text{-}perm}$ and $M_{wv\text{-}v}$ are to be taken for members above the neutral axis. The hogging bending moment values are to be taken for members below the neutral axis.

1.5.2.5 The design hull girder shear stress for the buckling assessment, $\tau_{hg\text{-}net50}$, is to be calculated based on net hull girder sectional properties and is to be taken as:

$$\tau_{hg\text{-}net50} = \left| (Q_{sw\text{-}perm} + Q_{wv}) \left(\frac{1000 q_v}{t_{ij\text{-}net50}} \right) \right| \quad \text{N/mm}^2$$

where

$Q_{sw\text{-}perm}$ = positive and negative still water permissible shear force for Static + Dynamic (S+D) design load combination, as applicable from Table 2.6.1 in Chapter 2 for the load case under consideration, in kN
Q_{wv} = positive or negative vertical wave shear, in kN, as defined in Chapter 2
Q_{vw} is to be taken as:
$Q_{wv\text{-}pos}$ for assessment with the positive permissible still water shear force
$Q_{wv\text{-}neg}$ for assessment with the negative permissible still water shear force
$t_{ij\text{-}net50}$ = net thickness for the plate ij, in mm
= $t_{ij\text{-}grs} - 0{,}5t_{corr}$
$t_{ij\text{-}grs}$ = gross plate thickness of plate ij, in mm. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of $t_{w\text{-}grs}$ and $t_{f\text{-}grs}$, in mm
$t_{w\text{-}grs}$ = gross thickness of the corrugation web, in mm
$t_{f\text{-}grs}$ = gross thickness of the corrugation flange, in mm
t_{corr} = corrosion addition, in mm, as defined in Ch 1,12
q_v = unit shear per mm for the plate being considered, defined in 1.4.2.2

NOTES

1. Maximum of the positive shear (still water + vertical wave) and negative shear (still water + vertical wave) is to be used as the basis for calculation of design shear stress.
2. All plate elements ij that contribute to the hull girder shear capacity are to be assessed. *See also* Table 3.1.2 and Fig. 3.1.1.

1.5.2.6 The compressive buckling strength of plate panels is to satisfy the following criteria:

$\eta \leq \eta_{allow}$

where

η = buckling utilisation factor

$$f_{FOI} \frac{\sigma_{hg-net50}}{\sigma_{cr}}$$

$\sigma_{hg\text{-}net50}$ = hull girder compressive stress based on net hull girder sectional properties, in N/mm^2, as defined in 1.5.2.3

σ_{cr} = critical compressive buckling stress, σ_{xcr} or σ_{ycr} as appropriate, in N/mm^2, as specified in Ch 1,18.2.1.3. The critical compressive buckling stress is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness given as $t_{grs} - t_{corr}$ as described in Ch 1,12 is to be used for the calculation of σ_{cr}

η_{allow} = allowable buckling utilisation factor

= 1,0 for plate panels at or above 0,5*D*

= 0,90 for plate panels below 0,5*D*

t_{grs} = gross plate thickness, in mm

t_{corr} = corrosion addition, in mm, as defined in Ch 1,12.

1.5.2.7 The shear buckling strength of plate panels is to satisfy the following criteria:

$\eta \leq \eta_{allow}$

where

η = buckling utilisation factor

$$f_{FOI} \frac{\tau_{hg-net50}}{\tau_{cr}}$$

$\tau_{hg\text{-}net50}$ = design hull girder shear stress, in N/mm^2, as defined in 1.5.2.5

τ_{cr} = critical shear buckling stress, in N/mm^2, specified in Ch 1,18.2.1.3. The critical shear buckling stress is to be calculated for the effects of hull girder shear stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness $t_{grs} - t_{corr}$ as described in Ch 1,12 is to be used for the calculation of τ_{cr}

η_{allow} = allowable buckling utilisation factor

= 0,95

t_{grs} = gross plate thickness, in mm

t_{corr} = corrosion addition, in mm, as defined in Ch 1,12.

1.5.2.8 The compressive buckling strength of longitudinal stiffeners is to satisfy the following criteria:

$\eta \leq \eta_{allow}$

where

η = the greater of the buckling utilisation factors given in Ch 1,18.3.2.1 and 18.3.3.1. The buckling utilisation factor is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored

η_{allow} = allowable buckling utilisation factor

= 1,0 for stiffeners at or above 0,5*D*

= 0,90 for stiffeners below 0,5*D*.

1.6 Tapering and structural continuity of longitudinal hull girder elements

1.6.1 **Tapering based on minimum hull girder section property requirements**.

1.6.1.1 Scantlings required by the Rule minimum moment of inertia and section modulus may be gradually reduced to the local requirements at the ends, provided the hull girder bending and buckling requirements, as given in 1.3.3 and 1.5, are complied with along the full length of the ship.

1.6.2 **Longitudinal extent of higher strength steel**.

1.6.2.1 Where used, the application of higher strength steel is to be continuous over the length of the ship up to locations where the longitudinal stress levels are within the allowable range for mild steel structure.

1.6.3 **Vertical extent of higher strength steel**.

1.6.3.1 The vertical extent of higher strength steel, z_{hts}, used in the deck or bottom and measured from the moulded deck line at side or keel is not to be taken less than the following, *see also* Fig. 3.1.8.

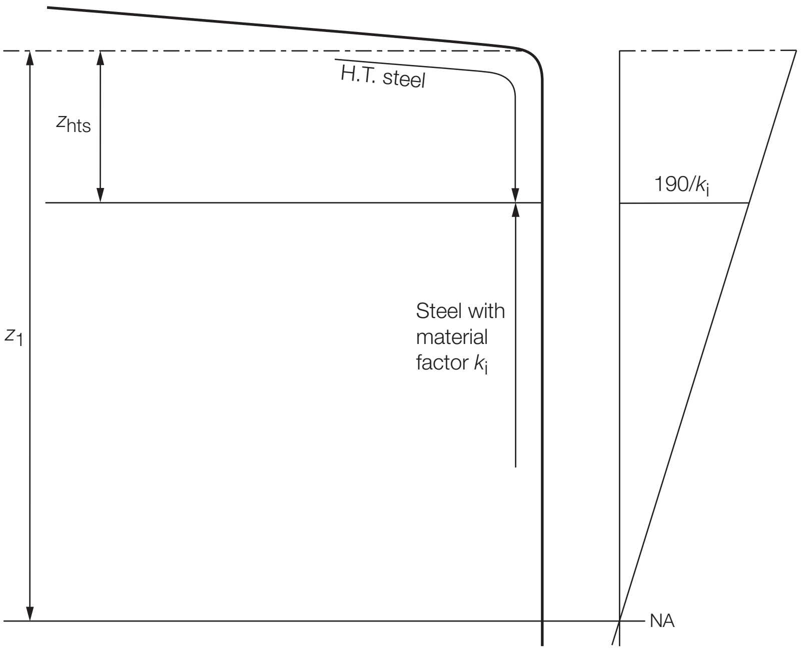


Fig. 3.1.8 Vertical extent of higher strength steel

$$z_{hts} = z_1 \left(1 - \frac{190}{\sigma_1 \, k_i}\right) \text{ m}$$

where

z_1 = distance from horizontal neutral axis to moulded deck line or keel respectively, in metres

σ_1 = to be taken as σ_{dk} or σ_{kl} for the hull girder deck and keel respectively, in N/mm^2

σ_{dk} = hull girder bending stress at moulded deck line given by

$$\frac{|M_{sw\text{-}perm} + M_{wv\text{-}v}|}{I_{v\text{-}net50}} (z_{dk\text{-}side} - z_{NA\text{-}net50})\, 10^{-3} \quad \text{N/mm}^2$$

σ_{kl} = hull girder bending stress at keel given by

$$\frac{|M_{sw\text{-}perm} + M_{wv\text{-}v}|}{I_{v\text{-}net50}} (z_{NA\text{-}net50} - z_{kl}) 10^{-3} \quad \text{N/mm}^2$$

$M_{sw\text{-}perm}$ = permissible hull girder still water bending moment for applicable static + dynamic condition, in kNm, as defined in Table 2.6.1 in Chapter 2

$M_{wv\text{-}v}$ = hogging and sagging vertical wave bending moments, in kNm, as defined in 1.2.2.4. $M_{wv\text{-}v}$ is to be taken as
$M_{wv\text{-}hog}$ for assessment with respect to hogging vertical wave bending moment
$M_{wv\text{-}sag}$ for assessment with respect to sagging vertical wave bending moment

$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, in m^4

$z_{dk\text{-}side}$ = distance from baseline to moulded deck line at side, in metres

z_{kl} = vertical distance from the baseline to the keel, in metres

$z_{NA\text{-}net50}$ = distance from baseline to horizontal neutral axis, in metres

k_i = higher strength steel factor for the area *i* defined in Fig. 3.1.8. The factor, *k*, is defined in 1.1.

1.6.4 **Tapering of plate thickness due to hull girder shear requirement**.

1.6.4.1 Longitudinal tapering of shear reinforcement is permitted, provided that the requirements given in 1.4.2 are complied with for any longitudinal position.

1.6.5 **Structural continuity of longitudinal bulkheads**.

1.6.5.1 Suitable scarphing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes. In particular, longitudinal bulkheads are to be terminated at an effective transverse bulkhead and large transition brackets shall be fitted in line with the longitudinal bulkhead.

1.6.6 **Structural continuity of longitudinal stiffeners.**

1.6.6.1 Where longitudinal stiffeners terminate, and are replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

1.6.6.2 Where a deck longitudinal stiffener is cut, in way of an opening, compensation is to be arranged to ensure structural continuity of the area. The compensation area is to extend well beyond the forward and aft ends of the opening and not be less than the area of the longitudinal that is cut. Stress concentration in way of the stiffener termination and the associated buckling strength of the plate and panel is to be considered.

1.7 Standard construction details

1.7.1 Details to be submitted

1.7.1.1 A booklet of standard construction details is to be submitted for review. It is to include the following:

(a) the proportions of built-up members to demonstrate compliance with established standards for structural stability.

(b) the design of structural details which reduce the harmful effects of stress concentrations, notches and material fatigue, such as:
  - details of the ends, at the intersections of members and associated brackets;
  - shape and location of air, drainage, and/or lightening holes;
  - shape and reinforcement of slots or cut-outs for internals;
  - elimination or closing of weld scallops in way of butts, ‘softening’ of bracket toes, reduction of abrupt changes of section or structural discontinuities;
  - proportion and thickness of structural members to reduce fatigue response due to machinery operational and/or wave induced cyclic stresses, particularly for higher strength steels.

1.8 Termination of local support members

1.8.1 **General**

1.8.1.1 In general, structural members are to be effectively connected to adjacent structures to avoid hard spots, notches and stress concentrations.

1.8.1.2 Where a structural member is terminated, structural continuity is to be maintained by suitable back-up structure fitted in way of the end connection of frames, or the end connection is to be effectively extended with additional structure and integrated with an adjacent beam, stiffener, etc.

1.8.1.3 All types of stiffeners (longitudinals, beams, frames, bulkhead stiffeners) are to be connected at their ends. However, in special cases, sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in 1.8.3 to 1.8.5.

1.8.2 **Longitudinal members**

1.8.2.1 All longitudinals are to be kept continuous within the 0,4L amidships cargo tank region. In special cases, in way of large openings, foundations and partial girders, the longitudinals may be terminated, but end connection and welding is to be specially considered.

1.8.2.2 Where continuity of strength of longitudinal members is provided by brackets, the correct alignment of the brackets on each side of the primary support member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross-sectional area are not less than those of the member.

1.8.3 **Bracketed connections**

1.8.3.1 At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member. The brackets are to have scantlings sufficient to compensate for the non-continuous stiffener flange or non-continuous stiffener.

1.8.3.2 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the section modulus less than that required for the stiffener.

1.8.3.3 Minimum net bracket thickness, $t_{bkt\text{-}net}$, is to be taken as:

$$t_{bkt\text{-}net} = (2 + f_{bkt} \quad Z_{rl\text{-}net})\left(\sqrt{\frac{\sigma_{yd\text{-}stf}}{\sigma_{yd\text{-}bkt}}}\right) \text{ mm, but is not to be less than 6 mm and need not be greater than 13,5 mm}$$

where:

f_{bkt} = 0,2 for brackets with flange or edge stiffener
= 0,3 for brackets without flange or edge stiffener
$Z_{rl\text{-}net}$ = net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener
$\sigma_{yd\text{-}stf}$ = specified minimum yield stress of the material of the stiffener, in N/mm^2
$\sigma_{yd\text{-}bkt}$ = specified minimum yield stress of the material of the bracket, in N/mm^2.

1.8.3.4 Brackets to provide fixity of end rotation are to be fitted at the ends of discontinuous local support members, except as otherwise permitted by 1.8.4. The end brackets are to have arm lengths, l_{bkt}, not less than:

$$l_{bkt} = c_{bkt} \sqrt{\frac{Z_{rl\text{-}net}}{t_{bkt\text{-}net}}} \text{ mm, but is not to be less than:}$$

(a) 1,8 times the depth of the stiffener web for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, *see* Fig. 3.1.9(c)
(b) 2,0 times for other cases, *see* Fig. 3.1.9(a), (b) and (d)

where

c_{bkt} = 65 for brackets with flange or edge stiffener
= 70 for brackets without flange or edge stiffener
$Z_{rl\text{-}net}$ = net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener
$t_{bkt\text{-}net}$ = minimum net bracket thickness, as defined in 1.8.3.3.

1.8.3.5 Where an edge stiffener is required, the depth of stiffener web, d_w, is not to be less than:

$$d_w = 45\left(1 + \frac{Z_{rl\text{-}net}}{2000}\right) \text{ mm, but is not to be less than 50 mm}$$

where

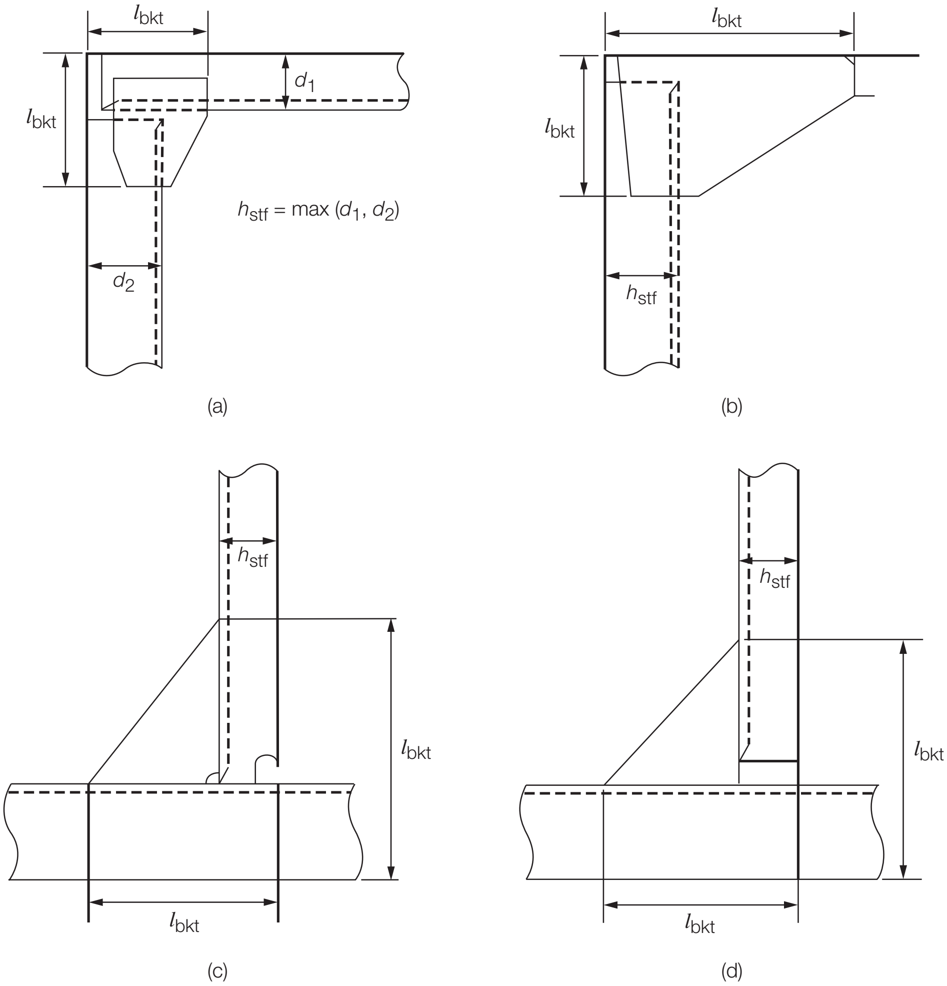
$Z_{rl\text{-}net}$ = net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener.

1.8.4 Bracketless connections

1.8.4.1 Local support members, for example, longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends, in accordance with the requirements of 1.8.2 and 1.8.3.

1.8.4.2 Where alternative connections are adopted, the proposed arrangements will be specially considered.

1.8.4.3 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.



NOTE
For stiffeners of configuration (b) that are not lapped, the bracket arm length l_{bkt} is not to be less than the stiffener height h_{stf}.
For stiffener arrangements similar to (c) and (d) where the smaller attached stiffener, labelled as h_{stf}, is connected to a primary support member or bulkhead, the height of the bracket is not to be less than the height of the attached stiffener, h_{stf}.

Fig. 3.1.9 Bracket arm length

1.8.5 Sniped ends

1.8.5.1 Stiffeners with sniped ends may be used where dynamic loads are small and where the incidence of vibration is considered to be small, i.e., structure not in the stern area and structure not in the vicinity of engines or generators, provided the net thickness of plating supported by the stiffener, $t_{p\text{-net}}$, is not less than:

$$t_{p\text{-net}} = c_1 \sqrt{\left(1000l - \frac{s}{2}\right)\frac{s\,P\,k}{1000}} \text{ mm}$$

where

l = stiffener span, in metres
s = stiffener spacing, in mm
P = design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets and method to derive the design pressure are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used:

(a) Table 3.2.5 in the cargo tank region
(b) Section 3.11.2.2 in the area forward of the forward cargo tank, and in the aft end
(c) Section 4.9.1 in the machinery space

k = higher strength steel factor, as defined in Ch 1,3.1.7

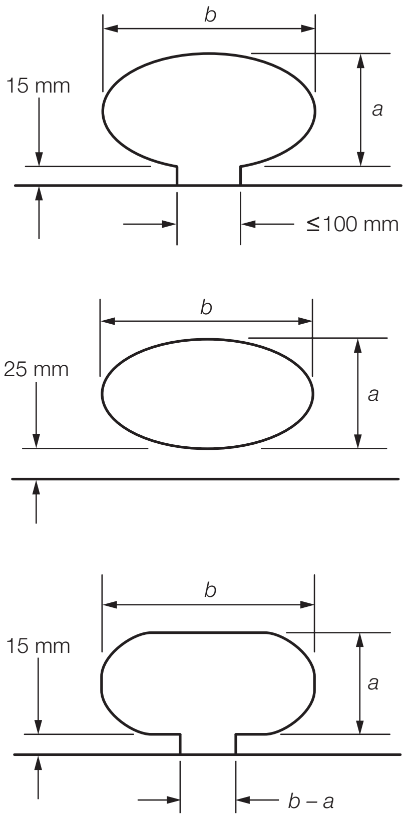
c_1 = coefficient for the design load set being considered, to be taken as:
= 1,2 for acceptance criteria set AC1
= 1,1 for acceptance criteria set AC2.

1.8.5.2 Bracket toes and sniped end members are, in general, to be kept within 25 mm of the adjacent member. The maximum distance is not to exceed 40 mm unless the bracket or member is supported by another member on the opposite side of the plating. Special attention is to be given to the end taper by using a sniped end of not more than 30 degrees. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15 mm.

1.8.5.3 The end attachments of non-load-bearing members may be snipe ended. The sniped end is to be not more than 30 degrees and is generally to be kept within 50 mm of the adjacent member unless it is supported by a member on the opposite side of the plating. The depth of the toe is generally not to exceed 15 mm.

1.8.6 Air and drain holes and scallops

1.8.6.1 Air, drain holes, scallops and block fabrication butts are to be kept at least 200 mm clear of the toes of end brackets, end connections and other areas of high stress concentration measured along the length of the stiffener toward the mid-span and 50 mm measured along the length in the opposite direction, *see* Fig. 3.1.10(b). In areas where the shear stress is less than 60 per cent of the allowable limit, alternative arrangements may be accepted. Openings are to be well-rounded. Fig. 3.1.10(a) shows some examples of air and drain holes and scallops. In general, the ratio of *a*/*b*, as defined in Fig. 3.1.10(a), is to be between 0,5 and 1,0. In fatigue-sensitive areas, further consideration may be required with respect to the details and arrangements of openings and scallops.



NOTE
The details shown in this figure are for guidance and illustration only.

Fig. 3.1.10(a)
Examples of air and drain holes and scallops

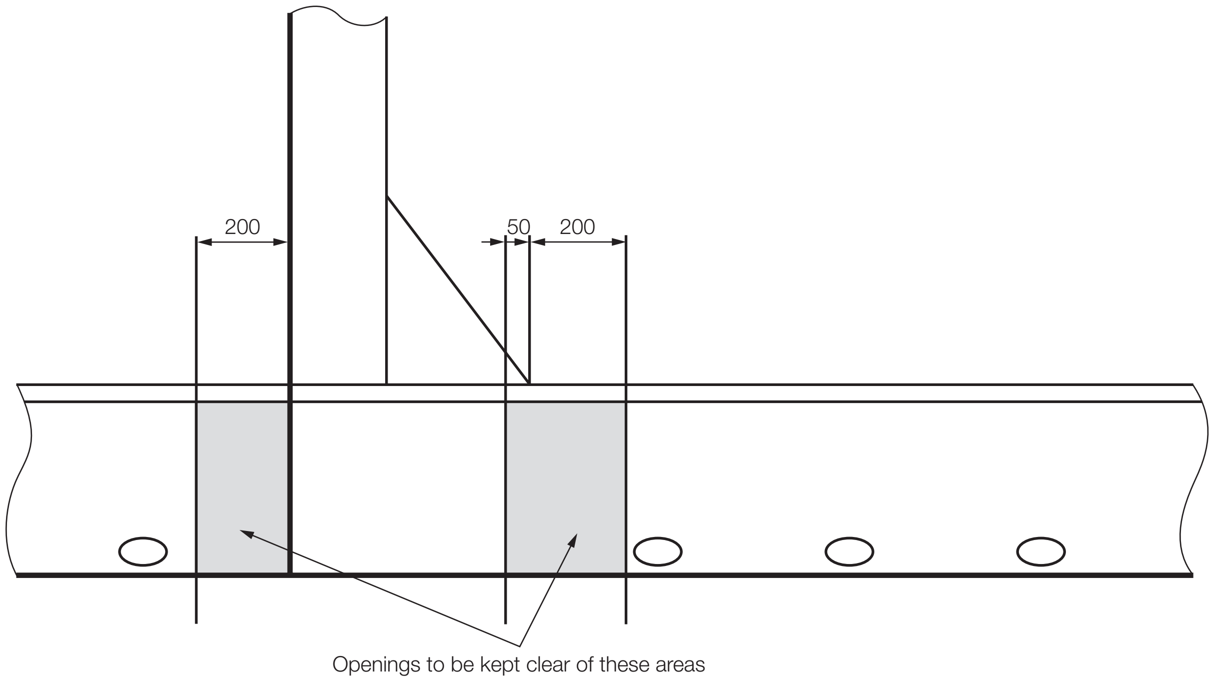


Fig. 3.1.10(b) Location of air and drain holes

1.8.7 **Special requirements**

1.8.7.1 Closely spaced scallops or drain holes, i.e., where the distance between scallops/drain holes is less than twice the width *b* as shown in Fig. 3.1.10(a), are not permitted in longitudinal strength members or within 20 per cent of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted, provided that they are of elliptical shape or equivalent to minimise stress concentration and are, in general, cut clear of the weld connection.

1.9 Termination of primary support members

1.9.1 General

1.9.1.1 Primary support members are to be arranged to ensure effective continuity of strength. Abrupt changes of depth or section are to be avoided. Primary support members in tanks are to form a continuous line of support and, wherever possible, a complete ring system.

1.9.1.2 The members are to have adequate lateral stability and web stiffening, and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well-rounded corners and are to be located considering the stress distribution and buckling strength of the panel.

1.9.2 End connection

1.9.2.1 Primary support members are to be provided with adequate end fixity by brackets or equivalent structure. The design of end connections and their supporting structure is to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.9.2.2 The ends of brackets are generally to be soft-toed. The free edges of the brackets are to be stiffened. Scantlings and details are given in 1.9.3.

1.9.2.3 Where primary support members are subject to concentrated loads, additional strengthening may be required, particularly if these are out of line with the member web.

1.9.2.4 In general, ends of primary support members or connections between primary support members forming ring systems are to be provided with brackets. Bracketless connections may be applied, provided that there is adequate support of the adjoining face plates.

1.9.3 Brackets

1.9.3.1 In general, the arm lengths of brackets connecting primary support members are not to be less than the web depth of the member, and need not be taken as greater than 1,5 times the web depth. The thickness of the bracket is, in general, not to be less than that of the girder web plate.

1.9.3.2 For a ring system where the end bracket is integral with the webs of the members and the face-plate is carried continuously along the edges of the members and the bracket, the full area of the largest face-plate is to be maintained close to the mid point of the bracket and gradually tapered to the smaller face-plates. Butts in face-plates are to be kept well clear of the bracket toes.

1.9.3.3 Where a wide face-plate abuts a narrower one, the taper is generally not to be greater than 1 in 4. Where a thick face-plate abuts against a thinner one and the difference in thickness is greater than 4 mm, the taper of the thickness is not to be greater than 1 in 3.

1.9.3.4 Face-plates of brackets are to have a net cross-sectional area, $A_{f\text{-}net}$, which is not to be less than:

$A_{f\text{-}net}$ = $l_{bkt\text{-}edge}\, t_{bkt\text{-}net}$ cm

where

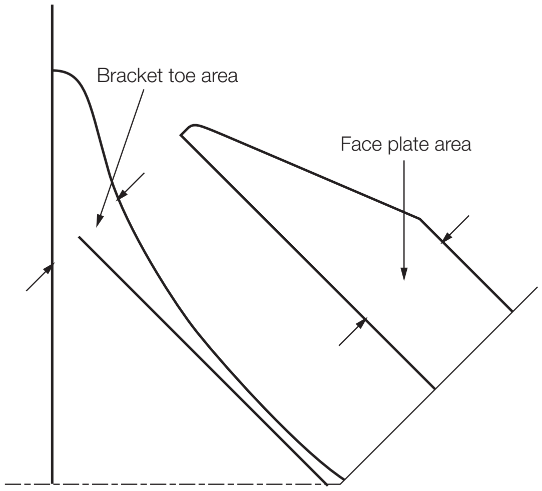
$l_{bkt\text{-}edge}$ = length of free edge of bracket, in metres. For brackets that are curved, the length of the free edge may be taken as the length of the tangent at the mid point of the free edge. If $l_{bkt\text{-}edge}$ is greater than 1,5 m, 40 per cent of the face-plate area is to be in a stiffener fitted parallel to the free edge and a maximum 0,15 m from the edge

$t_{bkt\text{-}net}$ = minimum net bracket thickness, in mm, as defined in 1.8.3.3.

1.9.4 Bracket toes

1.9.4.1 The toes of brackets are not to land on unstiffened plating. Notch effects at the toes of brackets may be reduced by making the toe concave or otherwise tapering it off. In general, the toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. The end brackets of large primary support members are to be soft-toed. Where any end bracket has a face-plate, it is to be sniped and tapered at an angle not greater than 30 degrees.

1.9.4.2 Where primary support members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face-plates, which are welded onto the edge of primary support member brackets, are to be carried well around the radiused bracket toe and are to incorporate a taper not greater than 1 in 3. Where sniped face-plates are welded adjacent to the edge of primary support member brackets, an adequate cross-sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area, measured perpendicular to the face-plate, is to be not less than 60 per cent of the full cross-sectional area of the face-plate, *see* Fig. 3.1.11.



NOTE
The details shown in this figure are only used to illustrate items described in the text and are not intended to represent design guidance or recommendations.

Fig. 3.1.11 Bracket toe construction

1.10 Intersections of continuous local support members and primary support members

1.10.1 **General**

1.10.1.1 Cut-outs for the passage of stiffeners through the web of primary support members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and on the attached web stiffeners.

1.10.1.2 Cut-outs in way of cross-tie ends and floors under bulkhead stools or in high stress areas are to be fitted with 'full' collar plates, *see* Fig. 3.1.12.

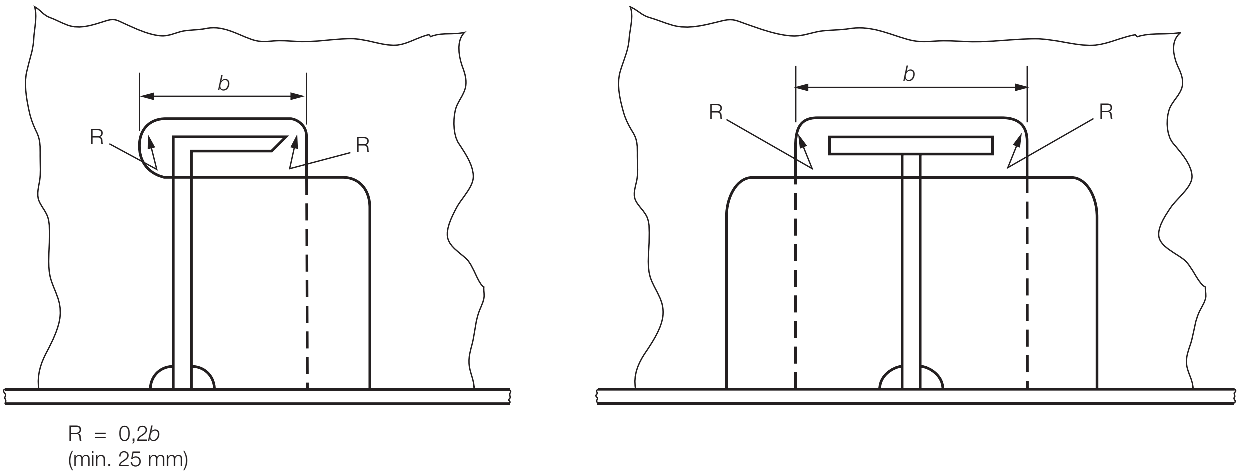


Fig. 3.1.12 Collars for cut-outs in areas of high stress

1.10.1.3 Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of 1.10.3, and in areas of significant stress concentrations, e.g., in way of primary support member toes.

1.10.1.4 When, in the following locations, the calculated direct stress, σ_W, in the primary support member web stiffener according to 1.10.3.5 exceeds 80 per cent of the permissible values, a soft heel is to be provided in way of the heel of primary support member web stiffeners:
(a) connection to shell envelope longitudinals below the deep load draught, T_{SC};
(b) connection to inner bottom longitudinals.
A soft heel is not required at the intersection with watertight bulkheads, where a back bracket is fitted or where the primary support member web is welded to the stiffener face-plate. The soft heel is to have a keyhole, similar to that shown in Fig. 3.1.14(c).

1.10.2 **Details of cut-outs**

1.10.2.1 In general, cut-outs are to have rounded corners and the corner radii, *R*, are to be as large as practicable, with a minimum of 20 per cent of the breadth, *b*, of the cut-out or 25 mm, whichever is greater, but need not be greater than 50 mm, *see* Fig. 3.1.12. Consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

1.10.3 **Connection between primary support members and intersecting stiffeners (local support members)**

1.10.3.1 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

1.10.3.2 The total load, *W*, transmitted through the connection to the primary support member is given by:

$$W = P\,s\left(S - \frac{s}{2000}\right) 10^{-3} \text{ kN}$$

where

P = design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets, method to derive the design pressure and applicable acceptance criteria set are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used:

Table 3.2.5 in the cargo tank region
3.11.2.2 in the area forward of the forward cargo tank
3.11.2.2 in the aft end
4.9.1 in the machinery space
Ch 3,6 if subjected to sloshing loads
Ch 3,6 if subjected to bottom slamming loads
Ch 3,6 if subjected to bow impact loads

S = primary support member spacing, in metres
s = stiffener spacing, in mm

For stiffeners having different primary support member spacing, *S*, and/or different pressure, *P*, at each side of the primary support member, the average load for the two sides is to be applied, e.g. vertical stiffeners at transverse bulkhead.

1.10.3.3 The load, W_1, transmitted through the shear connection is to be taken as follows:
If the web stiffener is connected to the intersecting stiffener:

$$W_1 = W\left(\alpha_a + \frac{A_{\text{l-net}}}{4f_c\,A_{\text{w-net}} + A_{\text{l-net}}}\right) \text{ kN}$$

If the web stiffener is not connected to the intersecting stiffener:

$$W_1 = W$$

where

W = the total load, in kN, as defined in 1.10.3.2
α_a = panel aspect ratio, not to be taken greater than 0,25
$= \dfrac{s}{1000S}$
S = primary support member spacing, in metres
s = stiffener spacing, in mm
$A_{\text{1-net}}$ = effective net shear area of the connection, to be taken as the sum of the components of the connection:

$A_{\text{ld-net}} + A_{\text{lc-net}}$ cm^2

in case of a slit type slot connections area, $A_{\text{1-net}}$, is given by:

$A_{\text{l-net}} = 2l_d\,t_{\text{w-net}}\,10^{-2}$ cm^2

in case of a typical double lug or collar plate connection area, $A_{\text{l-net}}$, is given by:

$A_{\text{l-net}} = 2f_1\,l_c\,t_{\text{c-net}}\,10^{-2}$ cm^2

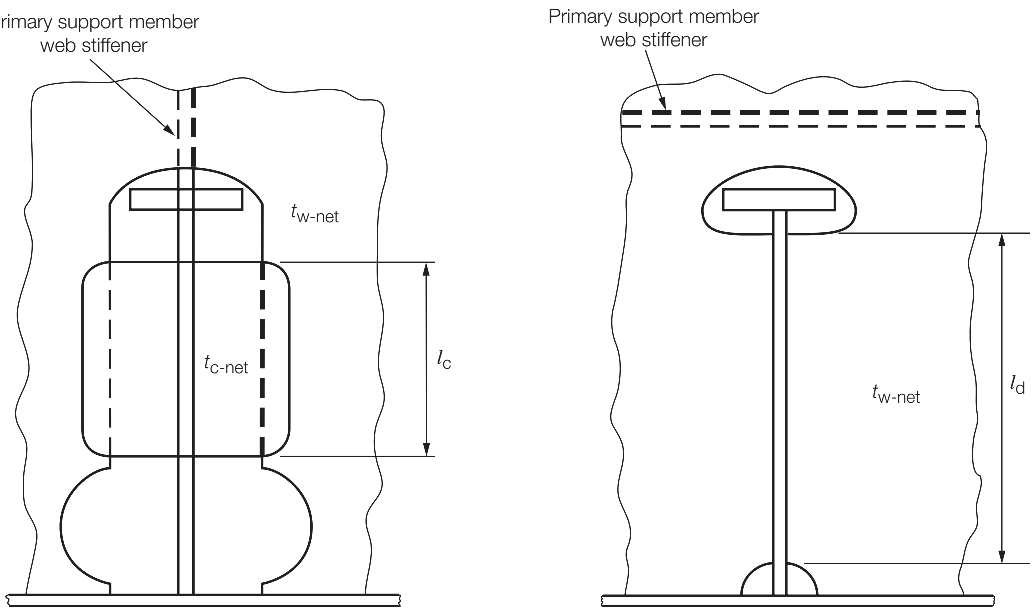
$A_{\text{1d-net}}$ = net shear connection area excluding lug or collar plate, as given by the following and Fig. 3.1.13:

$A_{\text{ld-net}} = l_d\,t_{\text{w-net}}\,10^{-2}$ cm^2

l_d = length of direct connection between stiffener and primary support member web, in mm
$t_{\text{w-net}}$ = net web thickness of the primary support member, in mm
$A_{\text{1c-net}}$ = net shear connection area with lug or collar plate, given by the following and Fig. 3.1.13:

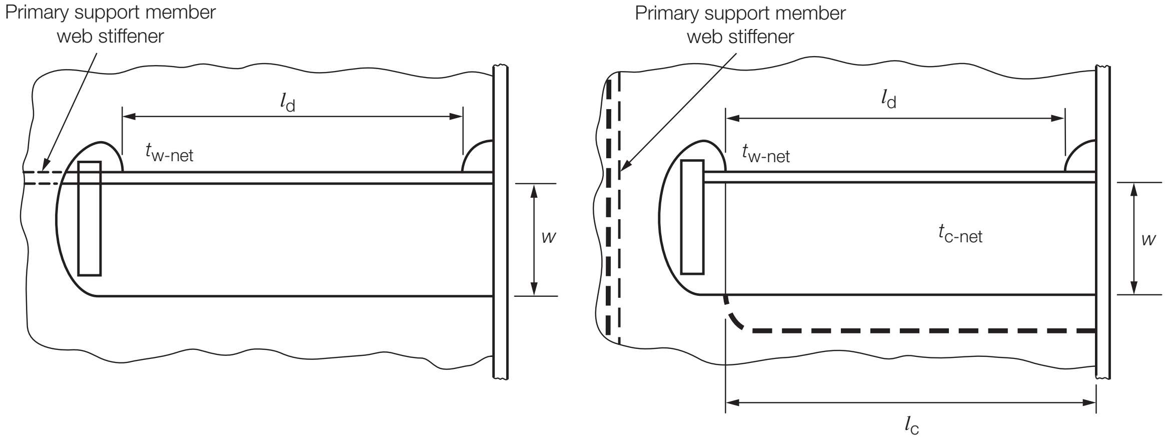
$A_{\text{lc-net}} = f_1\,l_c\,t_{\text{c-net}}\,10^{-2}$ cm^2

l_c = length of connection between lug or collar plate and primary support member, in mm
$t_{\text{c-net}}$ = net thickness of lug or collar plate, not to be taken greater than the net thickness of the adjacent primary support member web, in mm
f_1 = shear stiffness coefficient:
= 1,0 for stiffeners of symmetrical cross-section
$= \dfrac{140}{w}$ for stiffeners of asymmetrical cross-section but is not to be taken as greater than 1,0
w = the width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in Fig. 3.1.13
$A_{\text{w-net}}$ = effective net cross-sectional area of the primary support member web stiffener in way of the connection, including backing bracket where fitted, as shown in Fig. 3.1.14, in cm. If the primary support member web stiffener incorporates a soft heel ending or soft heel and soft toe ending, $A_{\text{w-net}}$, is to be measured at the throat of the connection, as shown in Fig. 3.1.14


Primary support member web stiffener
$t_{w\text{-net}}$
$t_{c\text{-net}}$
l_c
Primary support member web stiffener
$t_{w\text{-net}}$
l_d

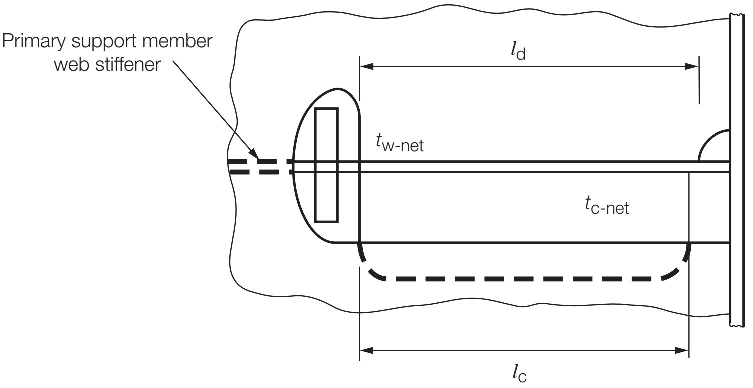
(a) Double lug or collar plates

(b) Slit type slot connection



(c) direct connection without lug or collar plate

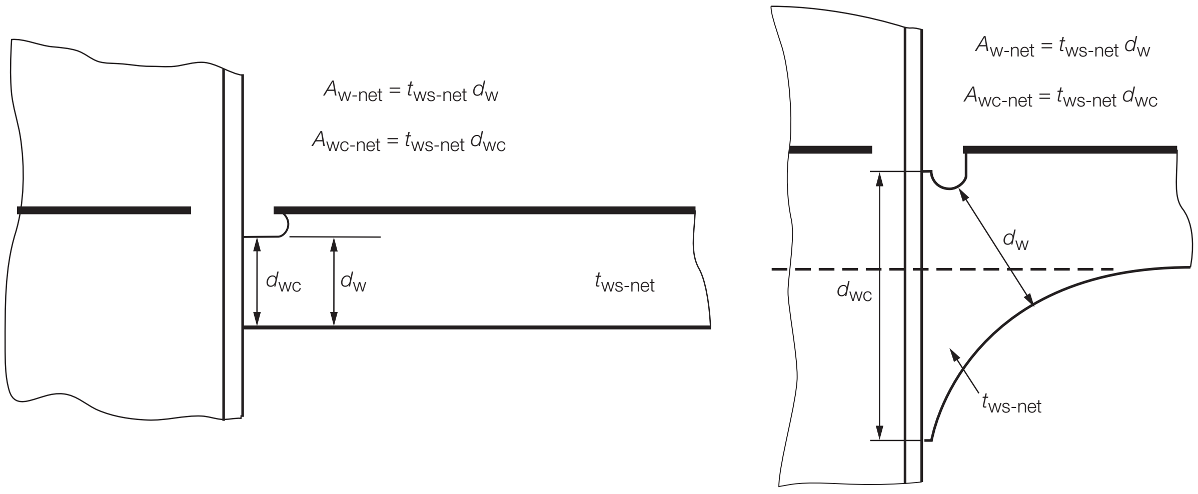
(d) Lug or collar plate and direct connection



(e) lug or collar plate and direct connection

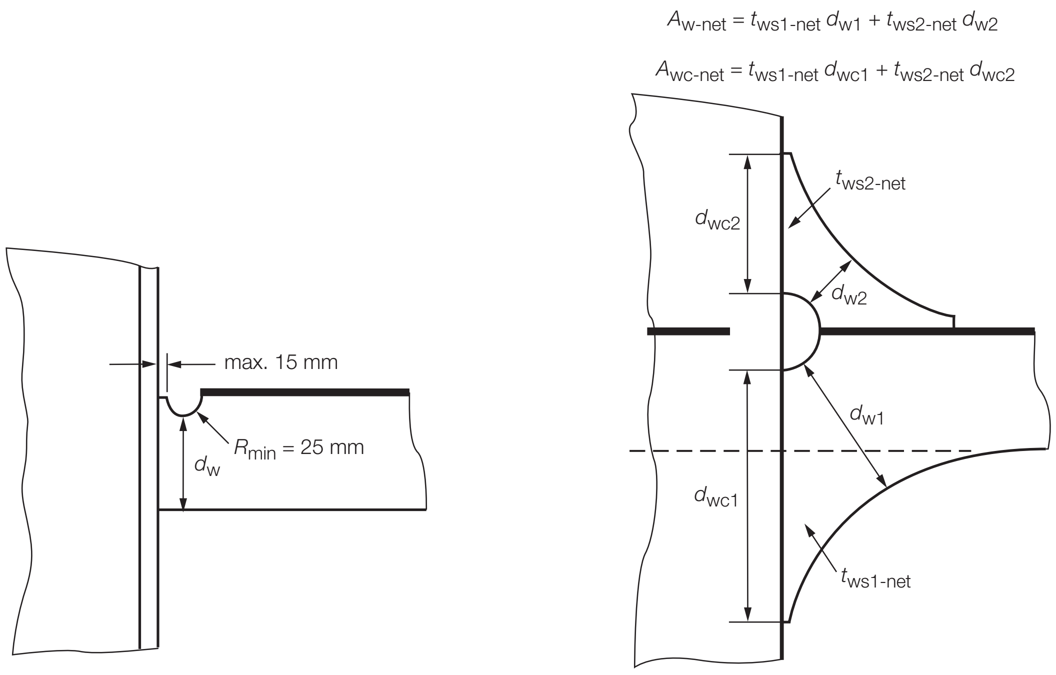
NOTE
The details shown in thid figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Fig. 3.1.13 Symmetric and asymmetric cut-outs


$A_{w\text{-net}} = t_{ws\text{-net}}\, d_w$
$A_{wc\text{-net}} = t_{ws\text{-net}}\, d_{wc}$
d_{wc}
d_w
$t_{ws\text{-net}}$
$A_{w\text{-net}} = t_{ws\text{-net}}\, d_w$
$A_{wc\text{-net}} = t_{ws\text{-net}}\, d_{wc}$
d_w
d_{wc}
$t_{ws\text{-net}}$

(a) Straight heel no bracket

(b) Soft toe and soft heel


$A_{w\text{-net}} = t_{ws1\text{-net}}\, d_{w1} + t_{ws2\text{-net}}\, d_{w2}$
$A_{wc\text{-net}} = t_{ws1\text{-net}}\, d_{wc1} + t_{ws2\text{-net}}\, d_{wc2}$
max. 15 mm
R_{min} = 25 mm
d_w
$t_{ws2\text{-net}}$
d_{wc2}
d_{w2}
d_{w1}
d_{wc1}
$t_{ws1\text{-net}}$

(c) Keyhole in way of soft heel

(d) Symmetrical soft toe brackets

where

$t_{ws\text{-net}}$, $t_{ws1\text{-net}}$ and $t_{ws2\text{-net}}$	net thickness of the primary support member web stiffener/backing bracket, in mm
d_w, d_{w1} and d_{w2}	minimum depth of the primary support member web stiffener/backing bracket, in mm
d_{wc}, d_{wc1} and d_{wc2}	length of connection between the primary support member web stiffener/backing bracket and the local support stiffener, in mm

NOTE
Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, see 1.10.1.4, the details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Fig. 3.1.14 Primary support member web stiffener details

f_c = the collar load factor defined as follows:
for intersecting stiffeners of symmetrical cross-section:
= 1,85 for $A_{w\text{-net}} \leq 14$
= $1{,}85 - 0{,}0441\,(A_{w\text{-net}} - 14)$ for $14 < A_{w\text{-net}} \leq 31$
= $1{,}1 - 0{,}013\,(A_{w\text{-net}} - 31)$ for $31 < A_{w\text{-net}} \leq 58$
= 0,75 for $A_{w\text{-net}} > 58$
for intersecting stiffeners of asymmetrical cross-section:

$$0{,}68 + 0{,}0172\,\frac{l_s}{A_{w\text{-net}}}$$

where
l_s = l_c for a single lug or collar plate connection to the primary support member
= l_d for a single sided direct connection to the primary support member
= mean of the connection length on both sides, i.e., in the case of a lug or collar plus a direct connection, $l_s = 0{,}5\,(l_c + l_d)$

1.10.3.4 The load, W_2, transmitted through the primary support member web stiffener is to be taken as follows:
If the web stiffener is connected to the intersecting stiffener:

$$W_2 = W\left(1 - \alpha_a - \frac{A_{1\text{-net}}}{4f_c\,A_{w\text{-net}} + A_{1\text{-net}}}\right)\ \text{kN}$$

If the web stiffener is not connected to the intersecting stiffener:
W_2 = 0
where
W = the total load, in kN, as defined in 1.10.3 2
α_a = panel aspect ratio
S = primary support member spacing, in metres
s = stiffener spacing, in mm
$A_{1\text{-net}}$ = effective net shear area of the connection, in cm^2, as defined in 1.10.3.3
f_c = collar load factor, as defined in 1.10.3.3
$A_{w\text{-net}}$ = effective net cross-sectional area of the primary support member web stiffener, in cm^2, as defined in 1.10.3.3

1.10.3.5 The values of $A_{w\text{-net}}$, $A_{wc\text{-net}}$ and $A_{1\text{-net}}$ are to be such that the calculated stresses satisfy the following criteria:
for the connection to the primary support member web stiffener away from the weld:

$$\sigma_w \leq \sigma_{perm}$$

for the connection to the primary support member web stiffener in way of the weld:

$$\sigma_{wc} \leq \sigma_{perm}$$

for the shear connection to the primary support member web:

$$\tau_w \leq \tau_{perm}$$

where
σ_w = direct stress in the primary support member web stiffener at the minimum bracket area away from the weld connection:
= $\dfrac{10W_2}{A_{w\text{-net}}}$ N/mm^2
σ_{wc} = direct stress in the primary support member web stiffener in way of the weld connection:
= $\dfrac{10W_2}{A_{wc\text{-net}}}$ N/mm^2
τ_w = shear stress in the shear connection to the primary support member
= $\dfrac{10W_1}{A_{1\text{-net}}}$ N/mm^2
$A_{w\text{-net}}$ = effective net cross-sectional area of the primary support member web stiffener, in cm^2, as defined in 1.10.3.3
$A_{wc\text{-net}}$ = effective net area of the web stiffener in way of the weld as shown in Fig. 3.1.14, in cm^2
$A_{1\text{-net}}$ = effective net shear area of the connection, in cm^2, as defined in 1.10.3.3
W_1 = load transmitted through the shear connection, in kN, as defined in 1.10.3.3
W_2 = load transmitted through the web stiffener, in kN, as defined in 1.10.3.4
σ_{perm} = permissible direct stress given in Table 3.1.5 for the applicable acceptance criteria, *see* 1.10.3.2, in N/mm^2
τ_{perm} = permissible shear stress given in Table 3.1.5 for the applicable acceptance criteria, *see* 1.10.3.2, in N/mm^2
when total load, W, is bottom slamming or bow impact loads, the following criteria apply in lieu of 1.10.3.3 to 1.10.3.5

$$0{,}9W \leq \frac{(A_{1\text{-net}}\,\tau_{perm} + A_{w\text{-net}}\,\sigma_{perm})}{10}\ \text{kN}$$

$A_{1\text{-net}}$ = effective net shear area in cm^2 of the connection, as defined in 1.10.3.3.
$A_{w\text{-net}}$ = effective net cross-sectional area in cm^2 of the primary support member web stiffener in way of the connection including backing bracket where fitted, as defined in 1.10.3.3.
σ_{perm} = permissible direct stress given in Table 3.1.5 for AC-3, in N/mm^2
τ_{perm} = permissible shear stress given in Table 3.1.5 for AC-3, in N/mm^2.

1.10.3.6 Where a backing bracket is fitted in addition to the primary support member web stiffener, it is to be arranged on the opposite side to, and in alignment with, the web stiffener. The arm length of the bracket is to be not less than the depth of the web stiffener and its net cross-sectional area through the throat of the bracket is to be included in the calculation of $A_{w\text{-net}}$ as shown in Fig. 3.1.14.

1.10.3.7 Lapped connections of primary support member web stiffeners or tripping brackets to local support members are not permitted in the cargo tank region, e.g., lapped connections between transverse and longitudinal local support members.

1.10.3.8 Fabricated stiffeners having their face plate welded to the side of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where such sections are connected to the primary support member web stiffener, a symmetrical arrangement of connection to the transverse members is to be incorporated. This may be implemented by fitting backing brackets on the opposite side of the transverse web or bulkhead. In way of the cargo tank region, the primary support member web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

1.10.3.9 Where the web stiffener of the primary support member is parallel to the web of the intersecting stiffener, but not connected to it, the offset primary support member web stiffener may be located as shown in Fig. 3.1.15. The offset primary support member web stiffener is to be located in close proximity to the slot edge, *see also* Fig. 3.1.15. The ends of the offset web stiffeners are to be suitably tapered and softened.

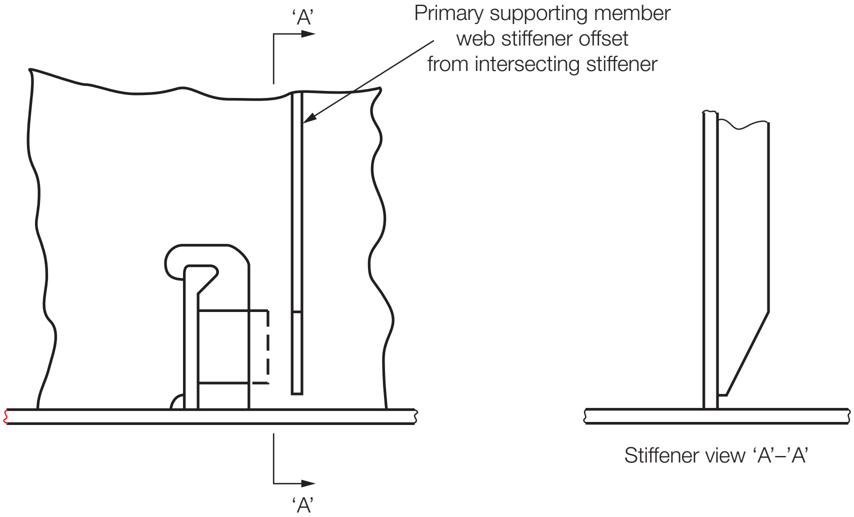

'A'
Primary supporting member web stiffener offset from intersecting stiffener
Stiffener view 'A'–'A'
'A'

Fig. 3.1.15 Offset primary support member web stiffeners

1.10.3.10 Alternative arrangements will be specially considered on the basis of their ability to transmit load with equivalent effectiveness. Details of calculations made and/or testing procedures and results are to be submitted.

1.10.3.11 The size of the fillet welds is to be calculated according to Pt 4, Ch 9, based on the weld factors given in Table 3.1.6. For the welding in way of the shear connection the size is not to be less than that required for the primary support member web plate for the location under consideration.

Table 3.1.5 Permissible stresses for connection between stiffeners and primary support members

Item	Direct stress, σ_{perm}, in N/mm^2			Shear stress, τ_{perm}, in N/mm^2		
	Acceptance criteria set *see* 3.4.3.2			Acceptance criteria set *see* 3.4.3.2		
	AC1	AC2	AC3	AC1	AC2	AC3
Primary support member web stiffener	$0{,}83\sigma_{yd}$ (3)	σ_{yd}	σ_{yd}	—	—	—
Primary support member web stiffener to intersecting stiffener in way of weld connection:						
double continuous fillet	$0{,}58\sigma_{yd}$ (3)	$0{,}7\sigma_{yd}$ (3)	σ_{yd}	—	—	—
partial penetration weld	$0{,}83\sigma_{yd}$ (2)(3)	σ_{yd} (2)	σ_{yd}	—	—	—
Primary support member stiffener to intersecting stiffener in way of lapped welding	$0{,}5\sigma_{yd}$	$0{,}6\sigma_{yd}$	σ_{yd}	—	—	—
Shear connection including lugs or collar plates:						
single sided connection	—	—	—	$0{,}71\tau_{yd}$	$0{,}85\tau_{yd}$	τ_{yd}
double sided connection	—	—	—	$0{,}83\sigma_{yd}$	τ_{yd}	τ_{yd}

Symbols

τ_{perm} = permissible shear stress, in N/mm^2
σ_{perm} = permissible direct stress, in N/mm^2
σ_{yd} = minimum specified material yield stress, in N/mm^2

$$\tau_{yd} = \frac{\sigma_{yd}}{\sqrt{3}}, \text{ in N/mm}^2$$

NOTES

1. The stress computation on plate type members is to be performed on the basis of net thicknesses, whereas gross values are to be used in weld strength assessments, *see* 1.10.3.11.
2. The root face is not to be greater than one third of the gross thickness of the primary support member stiffener.
3. Allowable stresses may be increased by 5 per cent where a soft heel is provided in way of the heel of the primary support member web stiffener.

Table 3.1.6 Weld factors for connection between stiffeners and primary support members

Item	Weld factor
Primary support member stiffener to intersecting stiffener	$0{,}6\sigma_w/\sigma_{perm}$ not to be less than 0,38
Shear connection inclusive lug or collar plate	0,38
Shear connection inclusive lug or collar plate, where the web stiffener of the primary support member is not connected to the intersection stiffener	$0{,}6\tau_w/\tau_{perm}$ not to be less than 0,44

Symbol

τ_w = shear stress, as defined in 1.10.3.5
σ_w = direct stress, as defined in 1.10.3.5
τ_{perm} = permissible shear stress, in N/mm^2, *see* Table 3.1.5
σ_{perm} = permissible direct stress, in N/mm^2, *see* Table 3.1.5

1.11 Openings

1.11.1 **General**.

1.11.1.1 Openings are to have well rounded corners.

1.11.1.2 Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory. Examples of high stress areas include:

(a) in vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one sixth of their length from either end;
(b) in floors or double bottom girders close to their span ends;
(c) above the heads and below the heels of pillars.

Where larger openings than given by 1.11.2 or 1.11.3 are proposed, the arrangements and compensation required will be specially considered.

1.11.2 **Manholes and lightening holes in single skin sections not requiring reinforcement**.

1.11.2.1 Openings cut in the web with depth of opening not exceeding 25 per cent of the web depth and located so that the edges are not less than 40 per cent of the web depth from the face-plate do not generally require reinforcement. The length of opening is not to be greater than the web depth or 60 per cent of the local support member spacing, whichever is greater. The ends of the openings are to be equidistant from the corners of cut-outs for local support members.

1.11.3 **Manholes and lightening holes in double skin sections not requiring reinforcement**.

1.11.3.1 Where openings are cut in the web and are clear of high stress areas, reinforcement of these openings is not required, provided that the depth of the opening does not exceed 50 per cent of the web depth and is located so that the edges are well clear of cut-outs for the passage of local support members.

1.11.4 **Manholes and lightening holes requiring reinforcement**.

1.11.4.1 Manholes and lightening holes are to be stiffened as required by 1.11.4.2 and 1.11.4.3.

1.11.4.2 The web plate is to be stiffened at openings when the mean shear stress, as determined by application of the requirements of Chapter 3, is greater than 50 N/mm^2 for acceptance criteria set AC1 or greater than 60 N/mm^2 for acceptance criteria set AC2. The stiffening arrangement is to ensure buckling strength, as required by Chapter 3.

1.11.4.3 On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400 mm, and in both directions if length of both axes is less than 300 mm. Edge reinforcement may be used as an alternative to stiffeners, *see* Fig. 3.1.16.

1.12 Local reinforcement

1.12.1 **Reinforcement at knuckles**.

1.12.1.1 Whenever a knuckle in a main member (shell, longitudinal bulkhead, etc.) is arranged, adequate stiffening is to be fitted at the knuckle to transmit the transverse load. This stiffening, in the form of webs, brackets or profiles, is to be connected to the transverse members to which they are to transfer the load (in shear), *see* Fig. 3.1.17.

1.12.1.2 In general, for longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

1.12.1.3 Generally, the distance between the knuckle and the support stiffening described in 1.12.1.1 is not to be greater than 50 mm.

1.12.2 **Reinforcement for openings and attachments associated with means of access for inspection/maintenance purposes**.

1.12.2.1 Local reinforcement is to be provided, taking into account proper location and strength of all attachments to the hull structure for access for inspection/maintenance purposes.

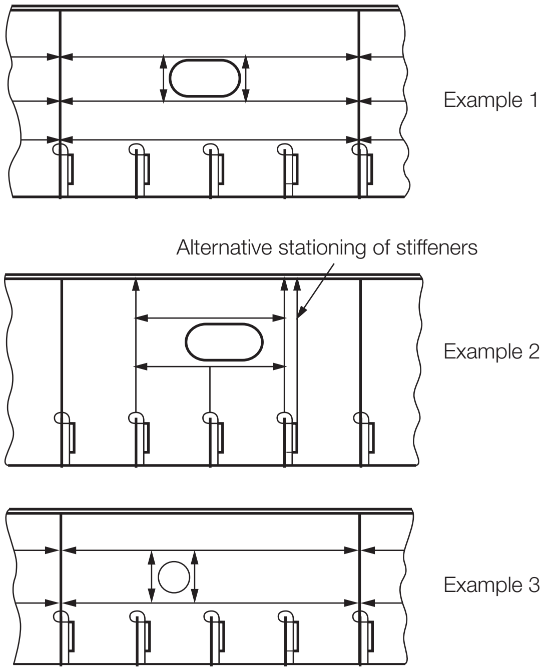


Fig. 3.1.16 Web plate with large openings

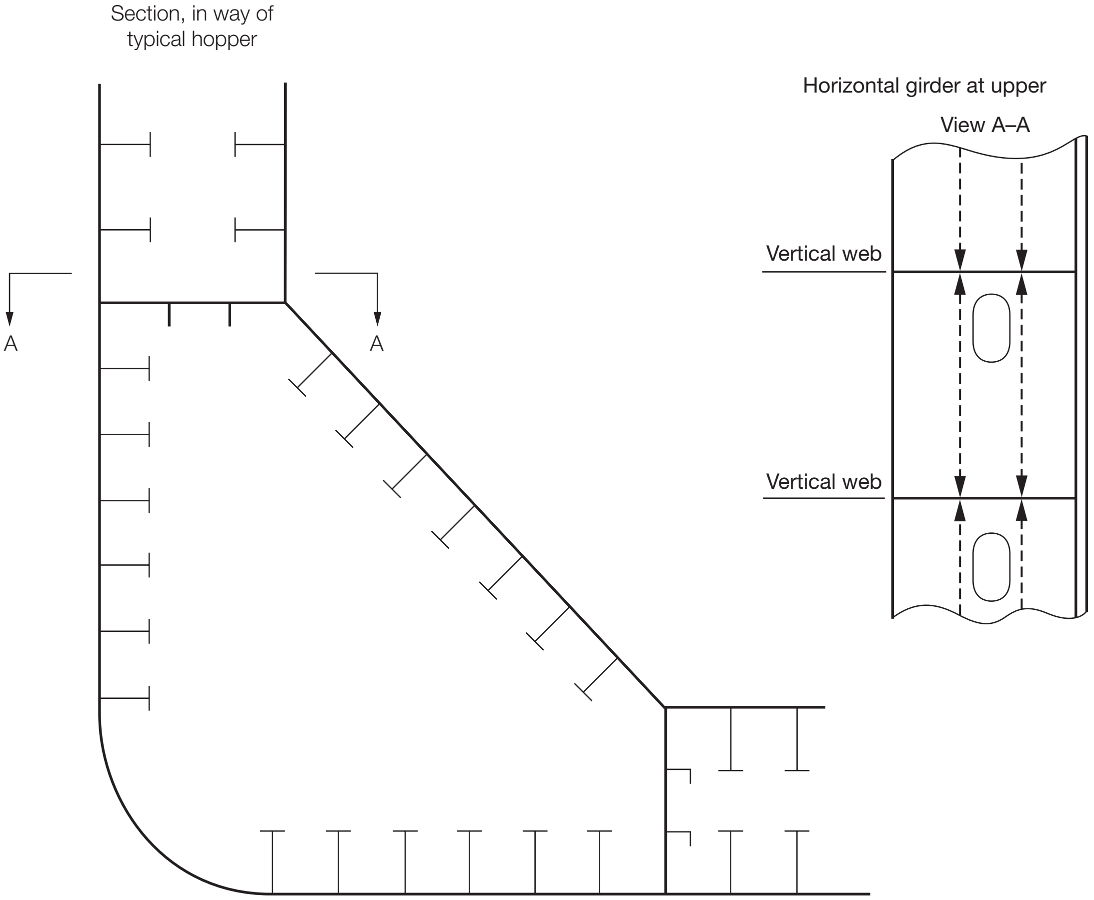


Fig. 3.1.17 Example of reinforcement at knuckles

Section 2
Cargo tank region

2.1 Symbols

2.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres
L_2 = Rule length, L, but need not be taken greater than 300 m
B = moulded breadth, in metres
D = moulded depth, in metres
T_{SC} = deep load draught, in metres
T_{LT} = minimum design light load draught, in metres
E = modulus of elasticity, in N/mm^2
σ_{yd} = specified minimum yield stress of the material, in N/mm^2
$\tau_{yd} = \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2
s = stiffener spacing, in mm
p = design pressure for the design load set being considered, in kN/m^2
g = acceleration due to gravity, 9,81 m/s^2
k = higher strength steel factor, defined in Ch 1,3.1.7.

2.2 General

2.2.1 **Application.**

2.2.1.1 The requirements of this Section apply to the hull structure within the cargo tank region of the ship unit.

2.2.2 **Evaluation of scantlings.**

2.2.2.1 Structural design details are to comply with the requirements given in 1.7 to 1.12.

2.2.2.2 The scantlings are to be assessed to ensure that the strength criteria are satisfied at all longitudinal positions, where applicable.

2.2.2.3 Local scantlings are to be increased where applicable to cover local variations, such as increased spacing, increased stiffener spans and green sea pressure loads. Local scantling increases may also be required to cover fore and aft end strengthening requirements, *see* Sections 3 and 5.

2.2.3 **General scantling requirements.**

2.2.3.1 The hull structure is to comply with the applicable requirements of:

- hull girder longitudinal strength, *see* Section 1;
- strength against sloshing and impact loads, *see* Section 6;
- hull girder ultimate strength, *see ShipRight*-FOI Procedure;
- strength assessment (FEM), *see ShipRight*-FOI Procedure;
- fatigue strength, *see ShipRight*-FOI Procedure;
- buckling, *see* Ch 1,18.

2.2.3.2 The net section modulus, shear areas and other sectional properties of the local and primary support members are to be determined in accordance with Ch 1,12.

2.2.4 **Minimum thickness for plating and local support members.**

2.2.4.1 The thickness of plating and stiffeners in the cargo tank region is to comply with the appropriate minimum thickness requirements given in Table 3.2.1.

2.2.5 **Minimum thickness for primary support members.**

2.2.5.1 The thickness of web plating and face plating of primary support members in the cargo tank region is to comply with the appropriate minimum thickness requirements given in Table 3.2.2.

Table 3.2.1 Minimum net thickness for plating and local support members in the cargo tank region

Scantling location			Net thickness (mm)
Plating	Shell	Keel plating	$6{,}0 + 0{,}04L_2$
		Bottom shell/bilge/side shell	$4{,}5 + 0{,}03L_2$
	Upper deck		$4{,}5 + 0{,}02L_2$
	Other structure	Hull internal tank boundaries	$4{,}5 + 0{,}02L_2$
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	$4{,}5 + 0{,}01L_2$
Local support members	Local support members on tight boundaries		$3{,}5 + 0{,}015L_2$
	Local support members on other structure		$2{,}5 + 0{,}015L_2$
Tripping brackets			$5{,}0 + 0{,}015L_2$

Table 3.2.2 Minimum net thickness for primary support members in cargo tank region

Scantling location	Net thickness (mm)
Bottom centreline girder	$5{,}5 + 0{,}025L_2$
Other bottom girders	$5{,}5 + 0{,}02L_2$
Bottom floors, web plates of side transverses and stringers in double hull	$5{,}0 + 0{,}015L_2$
Web and flanges of vertical web frames on longitudinal bulkheads, horizontal stringers on transverse bulkhead, deck transverses (above and below upper deck) and cross ties	$5{,}5 + 0{,}015L_2$

2.3 Hull envelope plating

2.3.1 Keel plating.

2.3.1.1 Keel plating is to extend over the flat of bottom for the complete length of the ship. The breadth, b_{kl}, is not to be less than:

$$b_{\text{kl}} = 800 + 5L_2 \text{ mm.}$$

2.3.1.2 The thickness of the keel plating is to comply with the requirements given in 2.3.2.

2.3.2 Bottom shell plating.

2.3.2.1 The thickness of the bottom shell plating is to comply with the requirements in Table 3.2.4.

2.3.3 Bilge plating.

2.3.3.1 The thickness of bilge plating is not to be less than that required for the adjacent bottom shell, *see* 2.3.2.1, or adjacent side shell plating, *see* 2.3.4.1, whichever is the greater.

2.3.3.2 The net thickness of bilge plating, t_{net}, without longitudinal stiffening is not to be less than:

$$t_{\text{net}} = \frac{\sqrt[3]{r^2 S_t P_{\text{ex}}}}{100} \text{ mm}$$

where

P_{ex} = design sea pressure from Table 3.2.7 calculated at the lower turn of bilge, in kN/m^2

r = effective bilge radius

= $r_0 + 0{,}5\,(a + b)$ mm

r_0 = radius of curvature, in mm, *see* Fig. 3.2.1

S_t = distance between transverse stiffeners, webs or bilge brackets, in metres

a = distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, *see* Fig. 3.2.1 and 2.4.1.2. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero

b = distance between the upper turn of bilge and the lowest side longitudinal, in mm, *see* Fig. 3.2.1 and 2.4.1.2. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero

Where the plate seam is located in the flat plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to extend to the adjacent plate above the bilge, provided that the plate seam is not more than $S_b/4$ below the lowest side longitudinal. Similarly, for flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be applied, provided that the plate seam is not more than $S_a/4$ beyond the outboard bottom longitudinal. Regularly longitudinally-stiffened bilge plating is to be assessed as a stiffened plate. The bilge keel is not considered as ‘longitudinal stiffening’ for the application of this requirement.

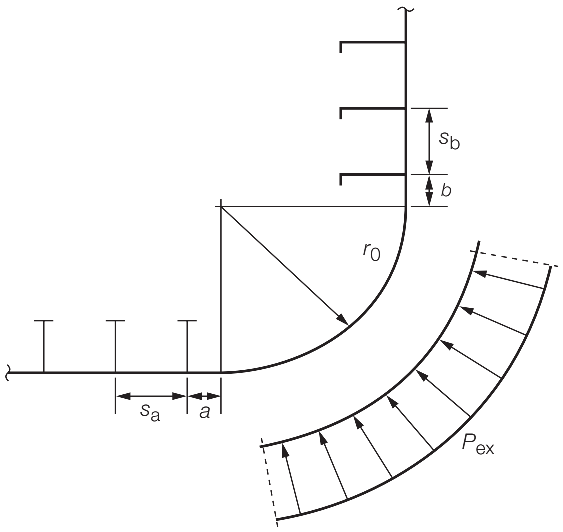


Fig. 3.2.1 Unstiffened bilge plating

2.3.3.3 Where bilge longitudinals are omitted, the bilge plate thickness outside 0,4*L* amidships will be considered in relation to the support derived from the hull form and internal stiffening arrangements. In general, outside of 0,4*L* amidships the bilge plate scantlings and arrangement are to comply with the requirements of ordinary side or bottom shell plating in the same region. Consideration is to be given where there is increased loading in the forward region.

2.3.4 Side shell plating.

2.3.4.1 The thickness of the side shell plating is to comply with the requirements in Table 3.2.4.

2.3.4.2 The net thickness, t_{net}, of the side plating within the range as specified in 2.3.4.3 is not to be less than:

$$t_{net} = 26\left(\frac{s}{1000} + 0{,}7\right)\left(\frac{BT_{SC}}{\sigma_{yd}^2}\right)^{0{,}25} \text{ mm.}$$

2.3.4.3 The thickness in 2.3.4.2 is to be applied to the following extent of the side shell plating, *see* Fig. 3.2.2:

(a) longitudinal extent:
- between a section aft of amidships where the breadth at the waterline exceeds 0,9*B*, and a section forward of amidships where the breadth at the waterline exceeds 0,6*B.*

(b) vertical extent:
- between 300 mm below the minimum design waterline at the light load draught, T_{LT}, amidships to 0,25T_{SC} or 2,2 m, whichever is greater, above the draught T_{SC}.

2.3.5 Sheerstrake.

2.3.5.1 The sheerstrake is to comply with the requirements in 2.3.4.

Table 3.2.3 Values of C_i

Bulkhead	At lower end of l_{cg}	At mid length of l_{cg}	At upper end of l_{cg}
Transverse bulkhead	C_1	C_{m1}	$0{,}80C_{m1}$
Longitudinal bulkhead	C_3	C_{m3}	$0{,}65C_{m3}$

where

$C_1 = a_1 + b_1 \sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0,60

$a_1 = 0{,}95 - \dfrac{0{,}41}{R_{bt}}$

$b_1 = -0{,}20 + \dfrac{0{,}078}{R_{bt}}$

$C_{m1} = a_{m1} + b_{m1} \sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0,55

$a_{m1} = 0{,}63 + \dfrac{0{,}25}{R_{bt}}$

$b_{m1} = -0{,}25 - \dfrac{0{,}11}{R_{bt}}$

$C_3 = a_3 + b_3 \sqrt{\dfrac{A_{dl}}{l_{dk}}}$ but is not to be taken as less than 0,60

$a_3 = 0{,}86 - \dfrac{0{,}35}{R_{bl}}$

$b_3 = -0{,}17 + \dfrac{0{,}10}{R_{bl}}$

$C_{m3} = a_{m3} + b_{m3} \sqrt{\dfrac{A_{dl}}{l_{dk}}}$ but is not to be taken as less than 0,55

$a_{m3} = 0{,}32 + \dfrac{0{,}24}{R_{bl}}$

$b_{m3} = -0{,}12 - \dfrac{0{,}10}{R_{bl}}$

$R_{bt} = \dfrac{A_{bt}}{b_{ib}}\left(1 + \dfrac{l_{ib}}{b_{ib}}\right)\left(1 + \dfrac{b_{av\text{-}t}}{h_{st}}\right)$ for transverse bulkheads

$R_{bl} = \dfrac{A_{bl}}{l_{ib}}\left(1 + \dfrac{l_{ib}}{b_{ib}}\right)\left(1 + \dfrac{b_{av\text{-}l}}{h_{sl}}\right)$ for longitudinal bulkheads

A_{dt} = cross-sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m^2
= 0 if no upper stool is fitted
A_{dl} = cross-sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m^2
= 0 if no upper stool is fitted
A_{bt} = cross-sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m^2
A_{bl} = cross-sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m^2
$b_{av\text{-}t}$ = average width of transverse bulkhead lower stool, in metres. *See* Fig. 3.2.3
$b_{av\text{-}l}$ = average width of longitudinal bulkhead lower stool, in metres. *See* Fig. 3.2.3
h_{st} = height of transverse bulkhead lower stool, in metres. *See* Fig. 3.2.3
h_{sl} = height of longitudinal bulkhead lower stool, in metres. *See* Fig. 3.2.3
b_{ib} = breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in metres. *See* Fig. 3.2.3
b_{dk} = breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in metres. *See* Fig. 3.2.3
l_{ib} = length of cargo tank at the inner bottom level between transverse lower stools, in metres. *See* Fig. 3.2.3
l_{dk} = length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in metres. *See* Fig. 3.2.3

Table 3.2.4 Thickness requirements for plating

The minimum net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets, as given in Table 3.2.7, and given by

$$t_{net} = 0{,}0158\alpha_p\, s \sqrt{\frac{|P|}{C_a\,\sigma_{yd}}} \quad \text{mm}$$

where

α_p = correction factor for the panel aspect ratio

$= 1{,}2 - \dfrac{s}{2100 l_p}$ but is not to be taken as greater than 1,0

l_p = length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in metres

C_a = permissible bending stress coefficient for the design load set being considered

$= \beta_a - \alpha_a \dfrac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than C_{a-max}

Acceptance criteria set	Structural member		β_a	α_a	$C_{a\text{-}max}$
AC1	Longitudinal strength members	Longitudinally stiffened plating	0,9	0,5	0,8
		Transversely or vertically stiffened plating	0,9	1,0	0,8
	Other members		0,8	0	0,8
AC2	Longitudinal strength members	Longitudinally stiffened plating	1,05	0,5	0,95
		Transversely or vertically stiffened plating	1,05	1,0	0,95
	Other members, including watertight boundary plating		1,0	0	1,0

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the load calculation point

$$= \left(\frac{(z - z_{NA-net50})\, M_{v\text{-}total}}{I_{v\text{-}net50}} - \frac{y\, M_{h\text{-}total}}{I_{h\text{-}net50}}\right) 10^{-3} \quad \text{N/mm}^2$$

$M_{v\text{-}total}$ = design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw\text{-}perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}

$M_{h\text{-}total}$ = design horizontal bending moment at the longitudinal position under consideration for the design load set being considered, in kNm

$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4

$I_{h\text{-}net50}$ = net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4

y = transverse coordinate of load calculation point, in metres

z = vertical coordinate of the load calculation point under consideration, in metres

$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres

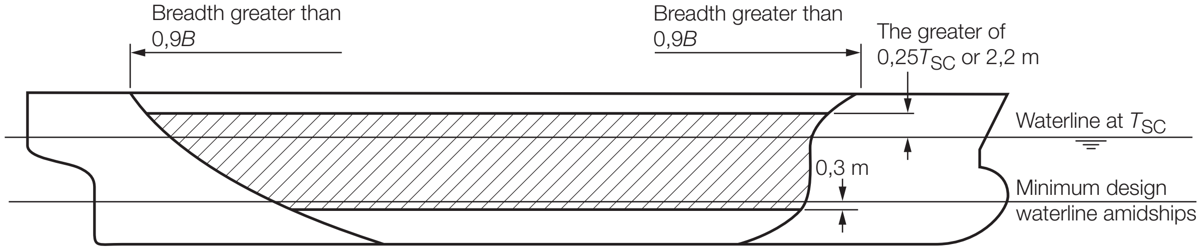

Breadth greater than 0,9B
Breadth greater than 0,9B
The greater of 0,25T_SC or 2,2 m
Waterline at T_SC
0,3 m
Minimum design waterline amidships

Fig. 3.2.2 Extent of side shell plating

2.3.5.2 The welding of deck fittings to rounded sheerstrakes is to be avoided within 0,6*L* of amidships.

2.3.5.3 Where the sheerstrake extends above the deck stringer plate, the top edge of the sheerstrake is to be kept free from notches and isolated welded fittings, and is to be smooth with rounded edges. Grinding may be required if the cutting surface is not smooth. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

2.3.6 Deck plating.

2.3.6.1 The thickness of the deck plating is to comply with the requirements given in Table 3.2.4.

2.4 Hull envelope framing

2.4.1 General.

2.4.1.1 The bottom shell, inner bottom and deck are to be longitudinally framed in the cargo tank region. The side shell, inner hull bulkheads and longitudinal bulkheads are generally to be longitudinally framed. Suitable alternatives which take account of resistance to buckling will be specially considered.

2.4.1.2 Where longitudinals are omitted in way of the bilge, a longitudinal is to be fitted at the bottom and at the side, close to the position where the curvature of the bilge plate starts. The distance between the lower turn of bilge and the outermost bottom longitudinal, a, is generally not to be greater than one third of the spacing between the two outermost bottom longitudinals, s_a. Similarly, the distance between the upper turn of the bilge and the lowest side longitudinal, b, is generally not to be greater than one third of the spacing between the two lowest side longitudinals, s_b. *See* Fig. 3.2.1.

2.4.2 Scantling criteria.

2.4.2.1 The section modulus and thickness of the hull envelope framing are to comply with the requirements given in Tables 3.2.5 and 3.2.6.

2.5 Inner bottom

2.5.1 Inner bottom plating.

2.5.1.1 The thickness of the inner bottom plating is to comply with the requirements given in Table 3.2.4.

2.5.1.2 In way of a welded hopper knuckle, the inner bottom is to be scarphed to ensure adequate load transmission to surrounding structure and reduce stress concentrations.

2.5.1.3 In way of corrugated bulkhead stools, where fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom.

2.5.2 Inner bottom longitudinals.

2.5.2.1 The section modulus and web plate thickness of the inner bottom longitudinals are to comply with the requirements given in Tables 3.2.5 and 3.2.6.

2.6 Bulkheads

2.6.1 General.

2.6.1.1 The inner hull and longitudinal bulkheads are generally to be longitudinally framed, and plane. Corrugated bulkheads are to comply with the requirements given in 2.6.6.

2.6.1.2 Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

2.6.2 Longitudinal tank boundary bulkhead plating.

2.6.2.1 The thickness of the longitudinal tank boundary bulkhead plating is to comply with the requirements given in Table 3.2.4.

Table 3.2.5 Section modulus requirements for stiffeners

The minimum net section modulus, Z_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and given by:

$$Z_{net} = \frac{|P|\, s l_{bdg}^{2}}{f_{bdg}\, C_s\, \sigma_{yd}} \quad \text{cm}^3$$

where

f_{bdg} bending moment factor:
for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends:
= 12 for horizontal stiffeners
= 10 for vertical stiffeners
for stiffeners with reduced end fixity, *see* Table 3.7.2

l_{bdg} = effective bending span, in metres

C_s = permissible bending stress coefficient for the design load set being considered, to be taken as:

Sign of hull girder bending Stress, σ_{hg}	Side pressure acting on	Acceptance criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \dfrac{\|\sigma_{hg}\|}{\sigma_{yd}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s\text{-}max}$
Compression (-ve)	Stiffener side	

Acceptance criteria set	Structural member	β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinal strength member	0,85	1,0	0,75
	Transverse or vertical member	0,75	0	0,75
AC2	Longitudinal strength member	1,0	1,0	0,9
	Transverse or vertical member	0,9	0	0,9
	Watertight boundary stiffeners	0,9	0	0,9

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the reference point

$$= \left(\frac{(z - z_{NA\text{-}net50})\, M_{v\text{-}total}}{I_{v\text{-}net50}} - \frac{y\, M_{h\text{-}total}}{I_{h\text{-}net50}} \right) \ \text{N/mm}^2$$

$M_{v\text{-}total}$ = design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm. $M_{v\text{-}total}$ is to be calculated in accordance with Table 2.6.1 in Chapter 2 using the permissible hogging or sagging still water bending moment, $M_{sw\text{-}perm}$, to be taken as:

Stiffener location	$M_{sw\text{-}perm}$	
	Pressure acting on plate side	Pressure acting on stiffener side
Above neutral axis	Sagging SWBM	Hogging SWBM
Below neutral axis	Hogging SWBM	Sagging SWBM

$M_{h\text{-}total}$ = design horizontal bending moment at longitudinal position under consideration for the design load set being considered, in kNm
$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4
$I_{h\text{-}net50}$ = net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4
y = transverse coordinate of the reference point, in metres
z = vertical coordinate of the reference point, in metres
$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres

Table 3.2.6 Web thickness requirements for stiffeners

The minimum net web thickness, $t_{w\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and given by

$$t_{w-net} = \frac{f_{shr}\,|P|\,s\,l_{shr}}{d_{shr}\,C_t\,\tau_{yd}} \text{ mm}$$

where

f_{shr} = shear force distribution factor:
for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends:
= 0,5 for horizontal stiffeners
= 0,7 for vertical stiffeners
for stiffeners with reduced end fixity, *see* Table 3.7.2
d_{shr} = effective shear depth, in mm
C_t = permissible shear stress coefficient for the design load set being considered, to be taken as
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2

2.6.2.2 Inner hull and longitudinal bulkheads are to extend as far forward and aft as practicable and are to be effectively scarphed into the adjoining structure.

2.6.3 Hopper side structure.

2.6.3.1 Knuckles in the hopper tank plating are to be supported by side girders and stringers, or by a deep longitudinal.

2.6.4 Transverse tank boundary bulkhead plating.

2.6.4.1 The thickness of the transverse tank boundary bulkhead plating is to comply with the requirements given in Table 3.2.4.

2.6.5 Tank boundary bulkhead stiffeners.

2.6.5.1 The section modulus and web thickness of stiffeners on longitudinal or transverse tank boundary bulkheads are to comply with the requirements given in Tables 3.2.5 and 3.2.6.

2.6.6 Corrugated bulkheads.

2.6.6.1 In general, corrugated bulkheads are to be designed with the corrugation angles, ϕ, between 55° and 90°, *see* Fig. 3.2.3.

2.6.6.2 The global strength of corrugated bulkheads, lower stools and upper stools, where fitted, and attachments to surrounding structures are to be verified with the cargo tank FEM model, in accordance with the *ShipRight*-FOI procedure, in the midship region. The global strength of corrugated bulkheads outside of midship region is to be considered, based on results from the cargo tank FEM model and using the appropriate pressure for the bulkhead being considered. Additional FEM analysis of cargo tank bulkheads forward and aft of the midship region may be necessary if the bulkhead geometry, structural details and support arrangement details differ significantly from bulkheads within the mid cargo tank region.

2.6.6.3 The net thicknesses, t_{net}, of the web and flange plates of corrugated bulkheads are to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and given by

$$t_{net} = 0{,}0158 b_p \sqrt{\frac{|P|}{C_a\,\sigma_{yd}}} \text{ mm}$$

where

b_p = breadth of plate:
= b_f for flange plating, in mm, *see* Fig. 3.2.3
= b_w for web plating, in mm, *see* Fig. 3.2.3
C_a = permissible bending stress coefficient
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2.

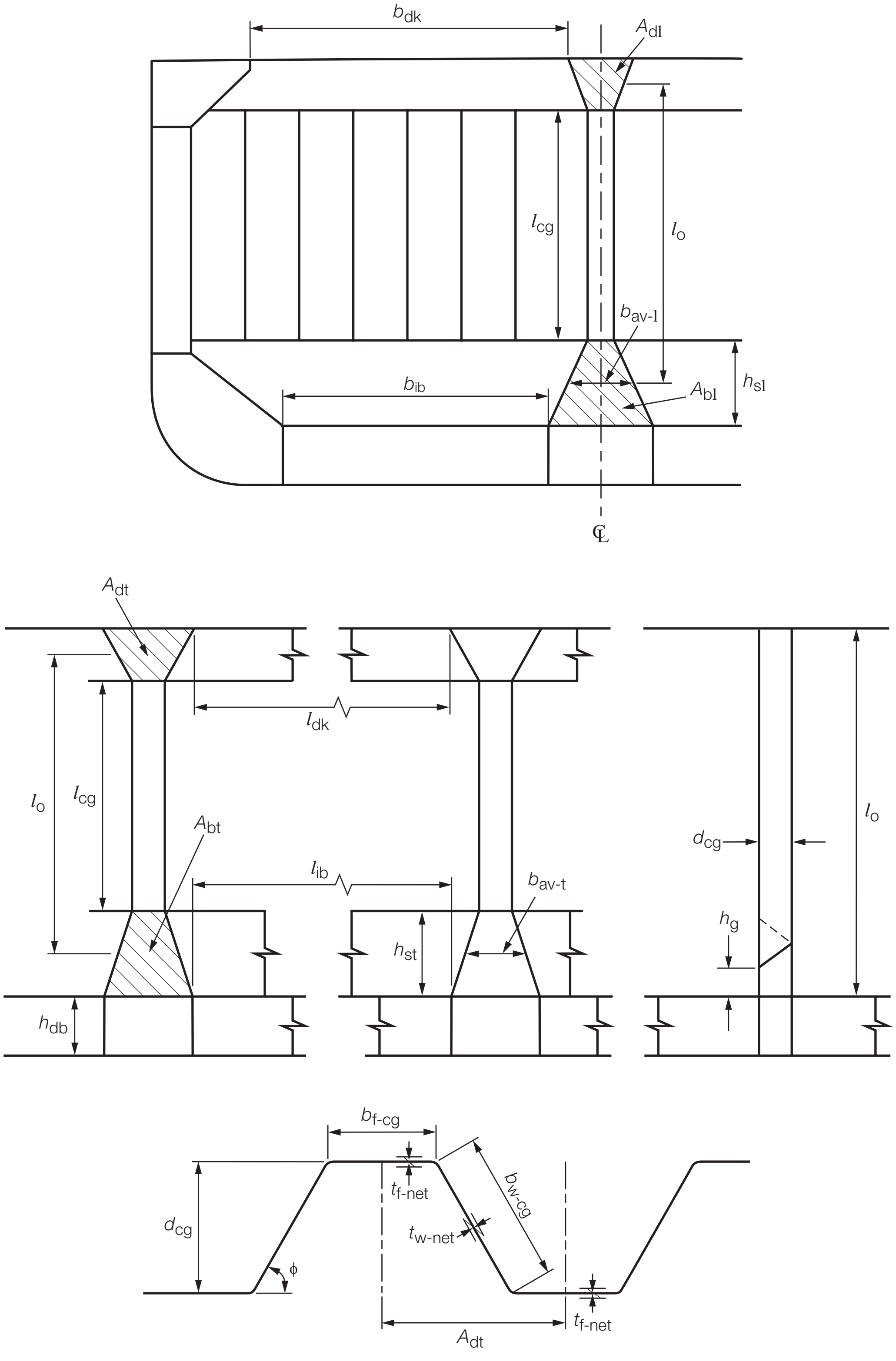


Fig. 3.2.3 Definition of parameters for corrugated bulkhead (units with longitudinal bulkhead at centreline)

2.6.6.4 Where the corrugated bulkhead is built with flange and web plate of different thickness, then the thicker net plating thickness, $t_{m\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and given by:

$$t_{m\text{–}net} = \sqrt{\frac{0{,}0005 b_p^2 \, |P|}{C_a \, \sigma_{yd}} - t_{n\text{-}net}^2} \quad \text{mm}$$

where
$t_{n\text{-}net}$ = net thickness of the thinner plating, either flange or web, in mm
b_p = breadth of thicker plate, either flange or web, in mm
C_a = permissible bending stress coefficient
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2.

2.6.7 **Vertically corrugated bulkheads.**

2.6.7.1 In addition to the requirements of 2.6.6, vertically corrugated bulkheads are also to comply with the following requirements.

2.6.7.2 The net plate thicknesses as required by 2.6.7.5 and 2.6.7.6 are to be maintained for two thirds of the corrugation length, l_{cg}, from the lower end, where l_{cg} is as defined in 2.6.7.3. Above that, the net plate thickness may be reduced by 20 per cent.

2.6.7.3 Where a lower stool is fitted, the net web plating thickness of the lower 15 per cent of the corrugation, $t_{w\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets from Table 3.2.7.

$$t_{w\text{–}net} = \frac{1000 |Q_{cg}|}{d_{cg} \, C_{t\text{-}cg} \, \tau_{yd}} \quad \text{mm}$$

where
Q_{cg} = design shear force imposed on the web plating at the lower end of the corrugation
$= \dfrac{s_{cg} \, l_{cg} \, |3P_l + P_u|}{8000}$ kN
P_l = design pressure for the design load set being considered, calculated at the lower end of the corrugation, in kN/m^2
P_u = design pressure for the design load set being considered, calculated at the upper end of the corrugation, in kN/m^2
s_{cg} = spacing of corrugation, in mm, *see* Fig. 3.2.3
l_{cg} = length of corrugation, which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, in metres, *see* Fig. 3.2.3
d_{cg} = depth of corrugation, in mm, *see* 2.6.7.4 and Fig. 3.2.3
$C_{t\text{-}cg}$ = permissible shear stress coefficient
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2.

2.6.7.4 The depth of the corrugation, d_{cg}, is not to be less than:

$$d_{cg} = \frac{1000 l_{cg}}{15} \quad \text{mm}$$

where
l_{cg} = length of corrugation, defined as the distance between the lower stool (or inner bottom if no lower stool is fitted) and the upper stool (or upper end if no upper stool is fitted), in metres, *see* Fig. 3.2.3.

2.6.7.5 Where a lower stool is fitted, the net thickness of the lower two thirds of the flanges of corrugated bulkheads, $t_{f\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7.

$$t_{f\text{–}net} = \frac{0{,}00657 b_f \sqrt{\sigma_{bdg\text{-}max}}}{C_f} \quad \text{mm}$$

where
$\sigma_{bdg\text{-}max}$ = maximum vertical bending stress in the flange. The bending stress is to be calculated at the lower end and at the midspan of the corrugation length
$= \dfrac{1000 M_{cg}}{Z_{cg\text{-}act\text{-}net}}$ N/mm^2
M_{cg} = as defined in 2.6.7.6
$Z_{cg\text{-}act\text{-}net}$ = actual net section modulus at the lower end and at the mid length of the corrugation, in cm^3
b_f = breadth of flange plating, in mm, *see* Fig. 3.2.3

b_w = breadth of web plating, in mm, *see* Fig.3.2.3
C_f = coefficient
= $7{,}65 - 0{,}26 \left(\frac{b_w}{b_f}\right)^2$

2.6.7.6 Where a lower stool is fitted, the net section modulus at the lower and upper ends and at the mid length of the corrugation, $Z_{cg\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7.

$$Z_{cg\text{-}net} = \frac{1000 M_{cg}}{C_{s\text{-}cg}\,\sigma_{yd}} \text{ cm}^3$$

where

$$M_{cg} = \frac{C_i\,|P|\,s_{cg}\,l_o^2}{12000} \text{ kNm}$$

$$P = \frac{P_u + P_l}{2} \text{ kN/m}^2$$

P_l, P_u = design pressure for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m^2:
for transverse corrugated bulkheads, the pressures are to be calculated at a section located at $b_{tk}/2$ from the longitudinal bulkheads of each tank
for longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e., the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead
b_{tk} = maximum breadth of tank under consideration measured at the bulkhead, in metres
s_{cg} = spacing of corrugation, in mm, *see* Fig. 3.2.3
l_o = effective bending span of the corrugation, measured from the mid depth of the lower stool to the mid depth of the upper stool, or upper end where no upper stool is fitted, in metres, *see* Fig. 3.2.3
l_{cg} = length of corrugation, defined as the distance between the lower stool and the upper stool, or the upper end where no upper stool is fitted, in metres, *see* Fig. 3.2.3
C_i = the relevant bending moment coefficients as given in Table 3.2.3
$C_{s\text{-}cg}$ = permissible bending stress coefficient
at middle of the corrugation length, l_{cg}
= c_e, but not to be taken as greater than 0,75 for acceptance criteria set AC1
= c_e, but not to be taken as greater than 0,90 for acceptance criteria set AC2
at the lower and upper ends of corrugation length, l_{cg}
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2

c_e = $\frac{2{,}25}{\beta} - \frac{1{,}25}{\beta^2}$ for $\beta \geq 1{,}25$
= 1,0 for $\beta < 1{,}25$

$$\beta = \frac{b_f}{t_{f\text{-}net}} \sqrt{\frac{\sigma_{yd}}{E}}$$

b_f = breadth of flange plating, in mm, *see* Fig. 3.2.3
$t_{f\text{-}net}$ = net thickness of the corrugation flange, in mm.

2.6.7.7 For tanks with effective sloshing breadth, b_{slh}, greater than 0,56B or effective sloshing length l_{slh}, greater than 0,13L, additional sloshing analysis is to be carried out to assess the section modulus of the unit corrugation.

2.6.7.8 For ships with a moulded depth equal to or greater than 16 m, a lower stool is to be fitted in compliance with the following requirements:

(a) general:
- the height and depth are not to be less than the depth of the corrugation;
- the lower stool is to be fitted in line with the double bottom floors or girders;
- the side stiffeners and vertical webs (diaphragms) within the stool structure are to align with the structure below, as far as is practicable, to provide appropriate load transmission to structures within the double bottom.

(b) stool top plating:
- the net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation;
- the extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

(c) stool side plating and internal structure:
- within the region of the corrugation depth from the stool top plate, the net thickness of the stool side plate is not to be less than 90 per cent of that required by 2.6.7.2 for the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength;
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by 2.6.2, 2.6.4 and 2.6.5 for transverse or longitudinal bulkhead plating and stiffeners;
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool;
- continuity is to be maintained, as far as practicable, between the corrugation web and supporting brackets inside the stool. The bracket net thickness is not to be less than 80 per cent of the required thickness of the corrugation webs and is to be of at least the same material yield strength;
- scallops in the diaphragms in way of the connections of the stool sides to the inner bottom and to the stool top plate are not permitted.

2.6.7.9 For ships with a moulded depth less than 16 m, the lower stool may be eliminated, provided the following requirements are complied with:

(a) General:
- Double bottom floors or girders are to be fitted in line with the corrugation flanges for transverse or longitudinal bulkheads, respectively;
- brackets/carlings are to be fitted below the inner bottom and hopper tank in line with corrugation webs. Where this is not practicable, gusset plates with shedder plates are to be fitted, *see* item (c) below and Fig. 3.2.3;
- the corrugated bulkhead and its supporting structure are to be assessed by Finite Element (FE) analysis, in accordance with the *ShipRight*-FOI procedure. In addition, the local scantlings requirements of 2.6.6.3 and 2.6.6.4 and the minimum corrugation depth requirement of 2.6.7.4 are to be applied.

(b) Inner bottom and hopper tank plating:
- The inner bottom and hopper tank in way of the corrugation are to be of at least the same material yield strength as the attached corrugation.

(c) Supporting structure:
- Within the region of the corrugation depth below the inner bottom, the net thickness of the supporting double bottom floors or girders is not to be less than the net thickness of the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength;
- the upper ends of vertical stiffeners on supporting double bottom floors or girders are to be bracketed to adjacent structure;
- brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0,5 times the corrugation depth and a net thickness not less than 80 per cent of the net thickness of the corrugation webs and are to be of at least the same material yield strength;
- cut outs for stiffeners in way of supporting double bottom floors and girders in line with corrugation flanges are to be fitted with full collar plates;
- where support is provided by gussets with shedder plates, the height of the gusset plate, *see* h_g in Fig. 3.2.3, is to be at least equal to the corrugation depth, and gussets with shedder plates are to be arranged in every corrugation. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates are not to be less than 100 per cent and 80 per cent, respectively, of the net thickness of the corrugation flanges and are to be of at least the same material yield strength. *See also* 2.6.7.11;
- scallops in brackets, gusset plates and shedder plates in way of the connections to the inner bottom or corrugation flange and web are not permitted.

2.6.7.10 In general, an upper stool is to be fitted in compliance with the following requirements:

(a) General:
- where no upper stool is fitted, finite element analysis is to be carried out in accordance with the *ShipRight*-FOI procedure to demonstrate the adequacy of the details and arrangements of the bulkhead support structure to the upper deck structure;
- side stiffeners and vertical webs (diaphragms) within the stool structure are to align with adjoining structure to provide for appropriate load transmission;
- brackets are to be arranged in the intersections between the upper stool and the structure on deck.

(b) Stool bottom plating:
- the net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation;
- the extension of the bottom plate beyond the corrugation is not to be less than the attached as-built flange thickness of the corrugation.

(c) Stool side plating and internal structure:
- within the region of the corrugation depth above the stool bottom plate, the net thickness of the stool side plate is to be not less than 80 per cent of that required by 2.6.7.2 for the corrugated bulkhead flange at the upper end, where the same material is used. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors (k);

- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners are not to be less than that required by 2.6.2, 2.6.4 and 2.6.5 for the transverse or longitudinal bulkhead plating and stiffeners;
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool;
- scallops in the diaphragms in way of the connections of the stool sides to the deck and to the stool bottom plate are not permitted.

2.6.7.11 Where gussets with shedder plates, or shedder plates (slanting plates), are fitted at the end connection of the corrugation to the lower stool or the inner bottom, appropriate means are to be provided to prevent the possibility of gas pockets being formed by these plates.

2.6.8 Non-tight bulkheads.

2.6.8.1 Non-tight bulkheads (wash bulkheads) are to be in line with transverse webs, bulkheads or similar structures. They are to be of plane construction, horizontally or vertically stiffened, and are to comply with the sloshing requirements given in the *ShipRight*–FOI procedure. In general, openings in the non-tight bulkheads are to have generous radii and their aggregate area is not to be less than 10 per cent of the area of the bulkhead.

2.7 Primary support members

2.7.1 General.

2.7.1.1 The scantlings of a primary support member are to comply with the minimum requirements of 2.2.5.

2.7.1.2 The shear area of a primary support member is, in general, to comply with the requirements of 7.3.3.5 when idealised as a simple beam.

2.7.1.3 The scantlings of all primary support members are to be verified by the Finite Element (FE) cargo tank structural analysis defined in the *ShipRight*–FOI procedure.

2.7.1.4 Primary support members are to be provided with adequate end fixity and in general be arranged in one plane to form continuous transverse rings.

2.7.1.5 Primary support members are to have adequate lateral stability and the webs stiffened in accordance with buckling requirements from Ch 1,18.

2.7.1.6 Primary support members that have open slots for stiffeners are to have a depth not less than 2,5 times the depth of the slots.

Table 3.2.7 **Design load sets for plating and local support members** (*see continuation*)

	Structural member		Space type	Operation on site			Inspection/maintenance			Transit/disconnected			Flooded		
				Draught	S	S+D	Draught	S	S+D	Draught	S	S+D	Draught	S	S+D
					Load	Load		Load	Load		Load	Load		Load	Load
EXTERNAL MEMBERS	Acceptance criteria				AC-1	AC-2		AC-1	AC-2		AC-1	AC-2		AC-2	AC-3
	Exposed deck	Space above deck	Green sea	Deep load		P_{ex}	Deep load		P_{ex}	Deep load		P_{ex}	Flooded		P_{ex}
		Space below deck	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}			
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}						
			Dry spaces												
	Bilge, side shell, sheerstrake	External sea	Sea water	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Flooded	P_{ex}	P_{ex}
		Inboard space	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}			
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}						
			Dry spaces												
	Keel, Bottom shell	External sea	Sea water	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Flooded	P_{ex}	P_{ex}
		Space above the panel	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}			
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}						
			Dry spaces	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}			

Table 3.2.7 Design load sets for plating and local support members (*continued*)

Structural member			Space type	Operation on site			Inspection/maintenance			Transit/disconnected			Flooded		
				Draught	S	S+D	Draught	S	S+D	Draught	S	S+D	Draught	S	S+D
					Load	Load		Load	Load		Load	Load		Load	Load
INTERNAL MEMBERS	Acceptance criteria				AC-1	AC-2		AC-1	AC-2		AC-1	AC-2		AC-2	AC-3
	Inner decks, Inner bottom tanktops	Space above deck	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}	Flooded	$P_{dk} + P_{in}$	$P_{dk} + P_{in}$
		Space below deck	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}
	Bilge, side shell, sheerstrake	Outboard space	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}
		Inboard space	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ Void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}

Table 3.2.7 Design load sets for plating and local support members (*conclusion*)

NOTES

1. When the unit's configuration cannot be described by Table 3.2.7, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents, and are to maximise the pressure on the structural boundary. The applicable draught is to be taken in accordance with the Design Load Set and this Table. Design Load Sets covering the S and S+D design load combinations are to be selected.
2. Load cases for exposed decks to consider any other distributed or concentrated loads, whereby simultaneously occurring green sea pressure may be ignored. Load cases for internal decks to consider any other distributed or concentrated loads when green sea pressure is not applicable.
3. Ship motion parameters of GM and k_r are to be selected according to the loading condition.
4. Light load draught to be taken as the minimum for the load scenario under consideration (Operation, Inspection/maintenance, Transit). The minimum draught may vary between load scenarios.
5. Deep load draught to be taken as the maximum for the load scenario under consideration (Operation, Inspection/maintenance, Transit). The maximum draught may vary between load scenarios.
6. Draughts for flooded conditions to be taken as the deepest flooded draught in way of compartment under assessment.
7. Under the assumption that the ship unit is at sea, external sea pressure will always be present. Therefore, the design load set to assess the external shell envelope when the dominant load direction is from inside the hull outwards, may be taken as P_{in}-P_{ex}.

■ Section 3
Forward of the forward cargo tank

3.1 Symbols

3.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres
L_2 = Rule length, L, but need not be taken greater than 300 m
B = moulded breadth, in metres
D = moulded depth, in metres
T_{SC} = deep load draught, in metres
T_{LT} = minimum design light load draught, in metres
E = modulus of elasticity, in N/mm^2
σ_{yd} = specified minimum yield stress of the material, in N/mm^2
τ_{yd} = $\dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2
s = stiffener spacing, in mm
p = design pressure for the design load set being considered, in kN/m^2
g = acceleration due to gravity, 9,81 m/s^2
k = higher strength steel factor, defined in Ch 1,3.1.7.

3.2 General

3.2.1 **Application**.

3.2.1.1 The requirements of this Section apply to structure forward of the forward end of the foremost cargo tank. Where the forward end of the foremost cargo tank is aft of 0,1L of the unit's length, measured from the F.P., special consideration will be given to the applicability of these requirements and the requirements of Section 2.

3.2.2 **General scantling requirements.**

3.2.2.1 The deck plating thickness and supporting structure are to be suitably reinforced in way of deck machinery and topside units.

3.2.3 **Structural continuity.**

3.2.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the forward end. *See also* 1.6.

3.2.3.2 All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed at their ends.

3.2.4 **Minimum thickness.**

3.2.4.1 In addition to the required scantlings given in this Section, the plating and stiffeners are to comply with the minimum thickness requirements for the cargo region given in Tables 3.2.1 and 3.2.2, except as given in Table 3.3.1.

Table 3.3.1 Minimum net thickness of structure forward of the forward cargo tank

Scantling location	Net thickness (mm)
Pillar bulkheads	7,5
Breasthooks	6,5
Floors and bottom girders	$5,5 + 0,02L_2$
Web plating of primary support members	$6,5 + 0,015L_2$

3.3 Bottom structure

3.3.1 Plate keel.

3.3.1.1 A flat plate keel is to extend as far forward as practical and is to satisfy the scantling requirements given in 2.3.1.

3.3.2 Bottom shell plating.

3.3.2.1 The thickness of the bottom shell plating is to comply with the requirements in 3.11.2.1.

3.3.3 Bottom longitudinals.

3.3.3.1 Bottom longitudinals are to be carried as far forward as practicable. Beyond this, suitably stiffened frames are to be fitted.

3.3.3.2 The section modulus and thickness of the bottom longitudinals are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

3.3.4 Bottom floors.

3.3.4.1 Bottom floors are to be fitted at each web frame location. The minimum depth of the floor at the centreline is not to be less than the depth of the floors within the cargo tank region.

3.3.5 Bottom girders.

3.3.5.1 A supporting structure is to be provided at the centreline either by extending the centreline girder to the stem or by providing a deep girder or centreline bulkhead.

3.3.5.2 Where a centreline girder is fitted, the minimum depth and thickness is not to be less than that fitted in the cargo tank region, and the upper edge is to be stiffened. Where a centreline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centreline girder.

3.3.6 Plate stems.

3.3.6.1 Plate stems are to be supported by stringers and flats, and by intermediate breasthook diaphragms spaced not more than 1500 mm apart, measured along the stem. Where the stem radius is large, a centreline support structure is to be fitted.

3.3.6.2 Between the minimum design light draught, T_{LT} at the stem and the deep load draught, T_{SC}, the plate stem net thickness, $t_{stem\text{-}net}$, is not to be less than:

$$t_{stem\text{-}net} = \frac{L_2 \sqrt{\dfrac{235}{\sigma_{yd}}}}{12} \text{ mm, but need not be taken as greater than 21 mm.}$$

Above the deep load draught, the thickness of the stem plate may be tapered to the requirements for the shell plating at the upper deck.
Below the minimum design light load draught, the thickness of the stem plate may be tapered to the requirements for the plate keel.

3.3.7 Floors and girders in spaces aft of the collision bulkhead.

3.3.7.1 Floors and girders which are aft of the collision bulkhead and forward of the forward cargo tank are to comply with the requirements in 3.3.4 and 3.3.5 and are to comply with the shear area requirements in 3.11.3.3.

3.4 Side structure

3.4.1 Side shell plating.

3.4.1.1 The thickness of the side shell plating is to comply with the requirements in 3.11.2.1. Where applicable, the thickness of the side shell plating is to comply with the requirements in 2.3.4.2.

3.4.1.2 Where a forecastle is fitted, the side shell plating requirements are to be applied to the plating extending to the forecastle deck elevation.

3.4.2 **Side shell local support members.**

3.4.2.1 Longitudinal framing of the side shell is to be carried as far forward as practicable.

3.4.2.2 The section modulus and thickness of the hull envelope framing are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

3.4.2.3 End connections of longitudinals at transverse bulkheads are to provide adequate fixity, lateral support, and, where not continuous, are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be used.

3.4.3 **Side shell primary support structure.**

3.4.3.1 In general, the spacing of web frames, S, is to be taken as

S = $2{,}6 + 0{,}005L_2$ m, but not to be taken greater than 3,5 m.

3.4.3.2 In general, for the transverse framing forward of the collision bulkhead, stringers are to be spaced approximately 3,5 m apart. Stringers are to have an effective span not greater than 10 m, and are to be adequately supported by web frame structures. Aft of the collision bulkhead, where transverse framing is adopted, the spacing of stringers may be increased.

3.4.3.3 Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10 m.

3.4.3.4 The scantlings of web frames supporting longitudinal frames, and stringers and/or web frames supporting transverse frames in the forward region are to be determined from 3.11.3, with the following additional requirements:

(a) Where no cross ties are fitted:
  - the required section modulus of the web frame is to be maintained for 60 per cent of the effective span for bending, measured from the lower end. The value of the bending moment used for calculation of the required section modulus of the remainder of the web frame may be appropriately reduced, but not greater than 20 per cent;
  - the required shear area of the lower part of the web frame is to be maintained for 60 per cent of the shear span measured from the lower end.

(b) Where one cross tie is fitted:
  - the effective spans for bending and shear of a web frame or stringer are to be taken, ignoring the presence of the cross tie. The shear forces and bending moments may be reduced to 50 per cent of the values that are calculated, ignoring the presence of the cross ties. For a web frame, the required section modulus and shear area of the lower part of the web frame are to be maintained up to the cross tie, and the required section modulus and shear area of the upper part of the web frame are to be maintained for the section above the cross tie;
  - cross ties are to be designed using the design loads specified in Table 3.2.7.

(c) Configurations with multiple cross ties are to be specially considered, in accordance with 3.4.3.4(d).

(d) Where complex grillage structures are employed, the suitability of the scantlings of the primary support members is to be determined by more advanced calculation methods.

3.4.3.5 The web depth of primary support members is not to be less than 14 per cent of the bending span and is to be at least 2,5 times as deep as the slots for stiffeners if the slots are not closed.

3.5 Deck structure

3.5.1 **Deck plating.**

3.5.1.1 The thickness of the deck plating is to comply with the requirements in 3.11.2.1 with the applicable lateral pressure, green sea and deck loads.

3.5.2 **Deck stiffeners.**

3.5.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in 3.11.2.2 and 3.11.2.3, with the applicable lateral pressure, green sea and deck loads.

3.5.3 **Deck primary support structure.**

3.5.3.1 The section modulus and shear area of primary support members are to comply with the requirements in 3.11.3.

3.5.3.2 The web depth of primary support members is not to be less than 10 per cent and 7 per cent of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2,5 times the depth of the slots if the slots are not closed. In the case of a grillage structure, the unsupported span is the distance between connections to other primary support members.

3.5.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

3.5.4 **Pillars.**

3.5.4.1 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

3.5.4.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

3.5.4.3 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45 per cent of the specified minimum yield stress of the material.

3.5.4.4 The scantlings of pillars are to comply with the requirements in 3.11.5.

3.5.4.5 Where the loads from heavy equipment exceed the design load of 3.11.5, the pillar scantlings are to be determined based on the actual loading.

3.6 Tank bulkheads

3.6.1 **General.**

3.6.1.1 Tanks may be required to have divisions or deep wash plates in order to minimise the dynamic stress on the structure.

3.6.2 **Construction.**

3.6.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

3.6.3 **Scantlings of tank boundary bulkheads.**

3.6.3.1 The thickness of tank boundary plating is to comply with the requirements in 3.11.2.1.

3.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

3.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in 3.11.3.

3.6.3.4 Web plating of primary support members is to have a depth of not less than 14 per cent of the unsupported span in bending, and is not to be less than 2,5 times the depth of the slots if the slots are not closed.

3.6.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in 3.11.4.

3.7 Watertight boundaries

3.7.1 **General.**

3.7.1.1 Watertight boundaries are to be fitted in accordance with Pt 4, Ch 3,5.

3.7.1.2 The number of openings in watertight bulkheads is to be kept to a minimum, compatible with the design and operation of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

3.7.2 **Scantlings of watertight boundaries.**

3.7.2.1 The thickness of boundary plating is to comply with the requirements in 3.11.2.1.

3.7.2.2 The section modulus and thickness of stiffeners are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

3.7.2.3 The section modulus and shear area of primary support members are to comply with the requirements in 3.11.3.

3.7.2.4 Web plating of primary support members is to have a depth of not less than 10 per cent of the unsupported span in bending, and is not to be less than 2,5 times the depth of the slots if the slots are not closed.

3.7.2.5 Scantlings of corrugated bulkheads are to comply with the requirements in 3.11.4.

3.8 Superstructure

3.8.1 Forecastle structure.

3.8.1.1 Forecastle structures are to be supported by girders with deep beams and web frames, and, in general, arranged in complete transverse belts and supported by lines of pillars extending down into the structure below. Deep beams and girders are to be arranged, where practicable, to limit the spacing between deep beams, web frames, and/or girders to about 3,5 m. Pillars are to be provided as required by 3.5.4. Main structural intersections are to be carefully developed with special attention given to pillar head and heel connections, and to the avoidance of stress concentrations.

3.9 Mooring systems

3.9.1 Supporting structure.

3.9.1.1 Where the structure is subjected to concentrated mooring loads from mooring arms or yokes, external turrets or mooring hawsers, etc., the scantlings and arrangements are to be specially considered. Finite element analysis of attachments to the hull is to be carried out to ensure satisfactory stress distribution of the mooring loads into the hull structure. The permissible local stress levels are to comply with the LR *ShipRight-FOI Design, Construction and Operation Procedure for Floating Offshore Installations* and Pt 4, Ch 6, as applicable.

3.10 Miscellaneous structures

3.10.1 Pillar bulkheads.

3.10.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders are to be stiffened to provide supports no less effective than required for stanchions or pillars. The acting load and the required net cross-sectional area of the pillar section are to be determined using the requirements of 3.5.4. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$, where t_{net} is the net thickness of plating, in mm.

3.10.1.2 Pillar bulkheads are to comply with the following requirements:
(a) the distance between bulkhead stiffeners is not to exceed 1500 mm;
(b) where corrugated, the depth of the corrugation is not to be less than 100 mm.

3.11 Scantling requirements

3.11.1 General.

3.11.1.1 The design load sets are to be applied to the structural requirements for the local support and primary support members, as given in Table 3.2.7. The static and dynamic load components are to be combined in accordance with Table 3.6.1 and the procedure given in Chapter 2.

3.11.2 Plating and local support members.

3.11.2.1 For plating subjected to lateral pressure, the net plating thickness, t_{net}, is to comply with the requirements of Table 3.2.4, where C_a is taken as given in Table 3.3.2.

3.11.2.2 For stiffeners subjected to lateral pressure, the net section modulus, Z_{net}, is to comply with the requirements of Table 3.2.5, where C_s is taken as given in Table 3.3.3.

3.11.2.3 For stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements, $t_{w\text{-}net}$, is to comply with the requirements of Table 3.2.6, where C_t is taken as given in Table 3.3.4.

Table 3.3.2 Permissible bending stress coefficient for plating

Acceptance criteria set	Structural member	C_a
AC1	All plating	0,80
AC2	Hull envelope plating	0,95
	Internal boundary plating	1,00

Table 3.3.3 Permissible bending stress coefficient for stiffeners

Acceptance criteria set	Structural member	C_s
AC1	All stiffeners	0,75
AC2	All stiffeners	0,90

Table 3.3.4 Permissible shear stress coefficient for stiffeners

Acceptance criteria set	Structural member	C_t
AC1	All stiffeners	0,75
AC2	All stiffeners	0,90

3.11.3 **Primary support members.**

3.11.3.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull. For side transverse frames, the requirements may be reduced due to the presence of cross ties, *see* 3.4.3.4.

3.11.3.2 For primary support members subjected to lateral pressure, the net section modulus, Z_{net50}, is to comply with 7.3.3.4 for all applicable design load sets in Table 3.2.7.

3.11.3.3 For primary support members subjected to lateral pressure, the effective net shear area, $A_{shr\text{-}net50}$, is to comply with 7.3.3.5 for all applicable design load sets in Table 3.2.7.

3.11.3.4 Primary support members are generally to be analysed with the specific methods described for the particular structure type. More advanced calculation methods may be necessary to ensure that nominal stress levels for all primary support members are less than the permissible stresses and stress coefficients given in 3.11.3.2 and 3.11.3.3 when subjected to the applicable design load sets.

3.11.4 **Corrugated bulkheads.**

3.11.4.1 Special consideration will be given to the approval of corrugated bulkheads, where fitted.

NOTE

Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, *see* 2.6.6 and 2.6.7.

3.11.5 **Pillars.**

3.11.5.1 The maximum load on a pillar, W_{pill}, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and is to be less than or equal to the permissible pillar load as given by the following equation, where $W_{\text{pill-perm}}$ is based on the net properties of the pillar:

$$W_{\text{pill}} \leq W_{\text{pill-perm}}$$

where

W_{pill} = applied axial load on pillar
= $P\, b_{\text{a-sup}}\, l_{\text{a-sup}} + W_{\text{pill–upr}}$ kN
$W_{\text{pill-perm}}$ = permissible load on a pillar
= $0{,}1 A_{\text{pill-net50}}\, \eta_{\text{pill}}\, \sigma_{\text{crb}}$ kN
$b_{\text{a-sup}}$ = mean breadth of area supported, in metres
$l_{\text{a-sup}}$ = mean length of area supported, in metres
$W_{\text{pill-upr}}$ = axial load from pillar or pillars above, in kN
$A_{\text{pill-net50}}$ = net cross-sectional area of the pillar, in cm^2
η_{pill} = utilisation factor for the design load set being considered:
= 0,5 for acceptance criteria set AC1
= 0,6 for acceptance criteria set AC2
σ_{crb} = critical buckling stress in compression of pillar based on the net sectional properties, in N/mm^2.

■ *Section 4*
Machinery space

4.1 Symbols

4.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length in metres
L_2 = Rule length, L, but need not be taken greater than 300 m
σ_{yd} = specified minimum yield stress of the material, in N/mm^2
s = stiffener spacing, in mm.

4.2 General

4.2.1 **Application.**

4.2.1.1 This Section prescribes scantling requirements for a machinery space or spaces located at any longitudinal frame location, such as a machinery space at the forward end. The requirements of this Section apply to all machinery spaces, regardless of location. For conventional self-propelled vessels, the requirements of Pt 3, Ch 7 of the Rules for Ships may also be used for guidance.

4.2.1.2 Where a machinery space is permitted to overlap either of the regions defined in Sections 3 and 5, the most onerous of the design requirements for the machinery space and the overlapping region are to take precedence.

4.2.1.3 Where a machinery space is located at a forward or aft region susceptible to local impact and slamming loads, the additional strengthening requirements prescribed in Section 6 are to be complied with in addition to the requirements in this Section.

4.2.2 **Arrangements.**

4.2.2.1 All machinery and related systems are to be supported to distribute the loads into the ship's structure. The adjacent structure is to be suitably stiffened.

4.2.2.2 Primary support members are to be positioned giving consideration to the provision of through stiffeners and in-line pillar supports to achieve an efficient structural design.

4.2.2.3 The scantlings of the structure and the area of attachments are to consider the weight, power and proportions of the machinery, especially where the engines are positioned relatively high in proportion to the width of the bed plate.

4.2.2.4 The foundations for main machinery and, where fitted, propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading. It is recommended that plans of the above structure be submitted to the machinery manufacturer for review.

4.2.2.5 A cofferdam is to be provided to separate the cargo tanks from the machinery space. Pump room, ballast tanks, or fuel oil tanks may be considered as cofferdams for this purpose.

4.2.2.6 When main auxiliary machinery is fitted above the weather deck, the machinery is to be protected by deckhouses, in accordance with Ch 1,10.1.1.

4.2.3 Minimum thickness.

4.2.3.1 In addition to the requirements for thickness, section modulus and shear area, as given in 4.3 to 4.9, the thickness of plating and stiffeners in the machinery space is to comply with applicable minimum thickness requirements for the cargo region given in Tables 3.2.1 and 3.2.2, except as applicable in Table 3.4.1.

Table 3.4.1 Minimum net thickness of structure in the machinery space

Scantling location		Net thickness (mm)
Plating	Lower decks and flats	$3,3 + 0,0067s$
	Inner bottom	$6,5 + 0,02L_2$
Floors and bottom longitudinal girders off centreline		$5,5 + 0,02L_2$
Web plating of primary support members		$5,5 + 0,015L_2$

4.3 Bottom structure

4.3.1 General

4.3.1.1 In general, a double bottom is to be fitted in the machinery space. The depth of the double bottom is to be at least the same as required in the cargo tank region. Where the depth of the double bottom in the machinery space differs from that in the adjacent spaces, continuity of the longitudinal material is to be maintained by sloping the inner bottom over a suitable longitudinal extent. Lesser double bottom height may be accepted in local areas, provided that the overall strength of the double bottom structure is not thereby impaired.

4.3.2 Bottom shell plating.

4.3.2.1 The keel plate breadth is to comply with the requirements in 2.3.1.1.

4.3.2.2 The thickness of the bottom shell plating (including keel plating) is to comply with the requirements in 4.9.1.1.

4.3.3 Bottom shell stiffeners.

4.3.3.1 The section modulus and thickness of bottom shell stiffeners are to comply with the requirements in 4.9.1.2 and 4.9.1.3.

4.3.4 Girders and floors.

4.3.4.1 The double bottom is to be arranged with a centreline girder.

4.3.4.2 Full depth bottom girders are to be arranged in way of the main machinery to distribute its weight effectively and to ensure rigidity of the structure. The girders are to be carried as far forward and aft as practicable, and be suitably supported at their ends to provide distribution of loads from the machinery. The girders are to be tapered beyond their required extent.

4.3.4.3 Where the bottom is transversely framed, plate floors are to be fitted at every frame.

4.3.4.4 Where the bottom is longitudinally framed, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

4.3.4.5 Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

4.3.5 **Inner bottom plating.**

4.3.5.1 Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19 mm. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer's recommendations.

4.3.6 **Sea chests**

4.3.6.1 Where the inner bottom or double bottom structure forms part of a sea chest, the thickness of the plating is not to be less than that required for the shell at the same location, taking into account the maximum unsupported width of the plating.

4.4 Side structure

4.4.1 **General.**

4.4.1.1 The scantlings of the side shell plating and longitudinals are to be properly tapered from the midship region towards the aft end.

4.4.1.2 A suitable scarphing arrangement of the longitudinal framing is to be arranged where the longitudinal framing terminates and is replaced by transverse framing.

4.4.1.3 Stiffeners and primary support members are to be supported at their ends.

4.4.2 **Side shell plating.**

4.4.2.1 The thickness of the side shell plating is to comply with the requirements in 4.9.1.1. Where applicable, the thickness of the side shell plating is to comply with the requirements in 2.3.4.2.

4.4.3 **Side shell local support members.**

4.4.3.1 The section modulus and thickness of side longitudinal and vertical stiffeners are to comply with the requirements in 4.9.1.2 and 4.9.1.3.

4.4.3.2 End connections of longitudinals at transverse bulkheads are to provide fixity, lateral support, and, when not continuous, are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be fitted.

4.4.4 **Side shell primary support members.**

4.4.4.1 Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.

4.4.4.2 The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces.

4.4.4.3 The section modulus and shear area of primary support members are to comply with the requirements in 4.9.2.

4.4.4.4 The web depth is to be not less than 2,5 times the web depth of the adjacent frames if the slots are not closed.

4.4.4.5 Web plating of primary support members is to have a depth of not less than 14 per cent of the unsupported span in bending.

4.5 Deck structure

4.5.1 **General.**

4.5.1.1 All openings are to be framed. Attention is to be paid to structural continuity. Abrupt changes of shape, section or plate thickness are to be avoided.

4.5.1.2 The corners of the machinery space openings are to be of suitable shape and design to minimise stress concentrations.

4.5.1.3 In way of machinery openings, deck or flats are to have sufficient strength where they are intended as effective supports for side transverse frames or web frames.

4.5.1.4 Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

4.5.1.5 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

4.5.1.6 Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

4.5.1.7 The structural scantlings are not to be less than the requirement for tank boundaries if the deck forms the boundary of a tank.

4.5.1.8 The structural scantlings are not to be less than the requirement for watertight bulkheads if the deck forms the boundary of a watertight space.

4.5.2 Deck scantlings.

4.5.2.1 The plate thickness of deck plating is to comply with the requirements in 4.9.1.1.

4.5.2.2 The section modulus and thickness of deck stiffeners are to comply with the requirements in 4.9.1.2 and 4.9.1.3.

4.5.2.3 The web depth of deck stiffeners is to be not less than 60 mm.

4.5.2.4 The section modulus and shear area of primary support members are to comply with the requirements in 4.9.2.

4.5.2.5 The web depth of primary support members is not to be less than 10 per cent and 7 per cent of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2,5 times the depth of the slots if the slots are not closed. In the case of a grillage structure, the unsupported span is the distance between connections to other primary support members.

4.5.2.6 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

4.5.3 Pillars.

4.5.3.1 Pillars are to comply with the requirements of 3.5.4.

4.5.3.2 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.

4.6 Machinery foundations

4.6.1 General.

4.6.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by foundations of sufficient strength to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

4.6.1.2 In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to be given to increase substantially the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case, and the thrust bearing.

4.6.1.3 For ship units with open floors in the machinery space, the foundations are generally to be arranged above the level of the top of the floors and securely bracketed.

4.6.2 Foundations for internal combustion engines and thrust bearings.

4.6.2.1 In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration is to be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

4.6.2.2 Generally, two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

Note

In general, the gross thickness of foundation top plates is not to be less than 45 mm, where the maximum continuous output of the propulsion machinery is 3500 kW or greater.

4.6.3 Auxiliary foundations.

4.6.3.1 Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

4.7 Tank bulkheads

4.7.1 General.

4.7.1.1 Tanks are to comply with the requirements of 3.6, with scantlings determined using the factors from Table 3.4.2 and Table 3.4.3.

Table 3.4.2 Permissible bending stress coefficient for plating

The permissible bending stress coefficient, C_a, for the design load set being considered is to be taken as:

$C_a = \beta_a - \alpha_a \dfrac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than $C_{a\text{-max}}$

where

β_a, α_a, $C_{a\text{-max}}$

Acceptance criteria set	Structural member		βa	α_a	$C_{a\text{-max}}$
AC1	Longitudinal strength members	Longitudinally stiffened plating	0,9	0,5	0,8
		Transversely or vertically stiffened plating	0,9	1,0	0,8
	Other members		0,8	0	0,8
AC2	Longitudinal strength members	Longitudinally stiffened plating	1,05	0,5	0,95
		Transversely or vertically stiffened plating	1,05	1,0	0,95
	Other members, including watertight boundary plating		1,0	0	1,0

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the load calculation point

= $\dfrac{(z - z_{NA\text{-net50}})\, M_{v\text{-total}}}{I_{v\text{-net50}}} 10^{-3}$ N/mm^2

$M_{v\text{-total}}$ = design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw\text{-perm}}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}, *see* Table 2.6.1 in Chapter 2

$I_{v\text{-net50}}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4

z = vertical coordinate of the load calculation point under consideration, in metres

$z_{NA\text{-net50}}$ = distance from the baseline to the horizontal neutral axis, in metres

4.8 Watertight boundaries

4.8.1 General.

4.8.1.1 Watertight boundaries are to comply with the requirements of 3.7, with scantlings determined using the factors from Table 3.4.2 and Table 3.4.3.

Table 3.4.3 Permissible bending stress coefficient for stiffeners

The permissible bending stress coefficient C_s is to be taken as:

Sign of hull girder bending stress, σ_{hg}	Side that pressure is acting on	Acceptance criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \dfrac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than $C_{s\text{-max}}$
Compression (–ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s\text{-max}}$
Compression (–ve)	Stiffener side	

where

β_s, α_s, $C_{s\text{-max}}$ = permissible bending stress factors and are to be taken as:

Acceptance criteria set	Structural member	β_s	α_s	$C_{s\text{-max}}$
AC1	Longitudinally effective stiffeners	0,85	1,0	0,75
	Other stiffeners	0,75	0	0,75
AC2	Longitudinally effective stiffeners	1,0	1,0	0,9
	Other stiffeners	0,9	0	0,9
	Watertight boundary stiffeners	0,9	0	0,9

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the reference point

$= \dfrac{(z - z_{NA\text{-}net50})\, M_{v\text{-}total}}{I_{v\text{-}net50}}\, 10^{-3}$ N/mm^2

$M_{v\text{-}total}$ = design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm
$M_{v\text{-}total}$ is to be calculated in accordance with Table 2.6.1 in Chapter 2 using the sagging or hogging still water bending moment

Stiffener location	$M_{sw\text{-}perm}$	
	Pressure acting on plate side	Pressure acting on stiffener side
Above neutral axis	Sagging SWBM	Hogging SWBM
Below neutral axis	Hogging SWBM	Sagging SWBM

$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4
z = vertical coordinate of the reference point, in metres
$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres

4.9 Scantling requirements

4.9.1 **Plating and local support members**.

4.9.1.1 For plating subjected to lateral pressure, the net plating thickness is to comply with the requirements of Table 3.2.4, where C_a is taken as given in Table 3.4.2.

4.9.1.2 For stiffeners subjected to lateral pressure, the net section modulus requirement is to comply with the requirements of Table 3.2.5, where C_s is taken as defined in Table 3.4.3.

4.9.1.3 For stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements is to comply with the requirements of Table 3.2.6, where C_t is taken as given in Table 3.3.4 in the previous Section.

4.9.2 **Primary support members.**

4.9.2.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull.

4.9.2.2 For primary support members subjected to lateral pressure, the net section modulus requirement is to comply with the requirements in 3.11.3.2.

4.9.2.3 For primary support members subjected to lateral pressure, the net cross-sectional area of the web is to comply with the requirements in 3.11.3.3.

4.9.2.4 Primary support members are generally to be analysed with the specific methods as described for the particular structure type. More advanced calculation methods may be required to ensure that nominal stress level, for all primary support members are less than permissible stresses and stress coefficients given in 3.11.3.2 and 3.11.3.3, when subjected to the applicable design load sets.

4.9.3 **Corrugated bulkheads.**

4.9.3.1 Special consideration will be given to the approval of corrugated bulkheads, where fitted.
NOTE
Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, *see* 2.6.6 and 2.6.7.

4.9.4 **Pillars.**

4.9.4.1 The maximum load on a pillar is to be less than the permissible pillar load as given by the requirements in 3.11.5.

■ *Section 5*
Aft end

5.1 Symbols

5.1.1 The symbols used in this Chapter are defined as follows:
L = Rule length, in metres
L_2 = Rule length, L, but need not be taken greater than 300 m
s = stiffener spacing, in mm.

5.2 General

5.2.1 **Application.**

5.2.1.1 The requirements of this Section apply to structure located between the aft peak bulkhead and the aft end of the ship.

5.2.1.2 The requirements of this Section do not apply to the following:
(a) rudder horns
(b) structures which are not integral with the hull, such as rudders, steering nozzles and propellers.
(c) other appendages permanently attached to the hull.
Where such items are fitted, the relevant requirements of the Rules for Ships are to be complied with.

5.2.1.3 The deck plating thickness and supporting structure are to be suitably reinforced for the steering gear, mooring windlasses, and other deck machinery.

5.2.2 **Structural continuity.**

5.2.2.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the aft end. *See also* 1.6.

5.2.2.2 Longitudinal framing of the strength deck is to be carried aft to the stern.

5.2.2.3 All shell frames and tank boundary stiffeners are, in general, to be continuous or bracketed at their ends.

5.2.3 Minimum thickness.

5.2.3.4 In addition to the scantling requirements as given in 5.3 to 5.8, the plating and stiffeners are to comply with the minimum thickness requirements for the cargo region, except as given in Table 3.5.1.

Table 3.5.1 Minimum net thickness of structure aft of the aft peak bulkhead

Scantling location	Net thickness (mm)
Pillar bulkhead plating	7,5
Bottom girders and aft peak floors	$5,5 + 0,02L_2$
Web plating of primary support members	$6,5 + 0,015L_2$

5.3 Bottom structure

5.3.1 General.

5.3.1.1 Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube, where fitted. Where floors do not extend to flats or decks, they are to be stiffened by flanges at their upper end.

5.3.1.2 The centreline bottom girder is to extend as far aft as is practicable and be suitably scarphed into the stern frame or transom.

5.3.1.3 For self-propelled units with conventional propulsion and steering arrangements, the relevant Sections of the Rules for Ships are to be complied with.

5.4 Shell structure

5.4.1 Shell plating.

5.4.1.1 The net thickness of the side shell and transom plating, t_{net}, is to comply with the requirements in 3.11.2.1.

5.4.1.2 The net plating thickness of shell, t_{net}, attached to the stern frame is to comply with the requirements in 3.11.2.1 and is not to be less than:

$t_{net} = 0,094 (L_2 - 43) + 0,009s$ mm

5.4.1.3 In way of the boss and heel plate, the shell net plating thickness, t_{net}, is not to be less than:

$t_{net} = 0,105 (L_2 - 47) + 0,011s$ mm

5.4.1.4 Within the extents specified in 2.3.4.3, the thickness of the side shell plating is to comply with the requirements in 2.3.4.2.

5.4.2 Shell local support members.

5.4.2.1 The section modulus and thickness of the hull envelope framing are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

5.4.3 Shell primary support members.

5.4.3.1 The requirements of 5.4.3 apply to single side skin construction supported by a system of vertical webs and/or horizontal stringers or flats.

5.4.3.2 Where a longitudinal framing system is adopted, longitudinals are to be supported by vertical primary support members extending from the floors to the upper deck. Deck transverses are to be fitted in line with the web frames.

5.4.3.3 Where a transverse framing system is adopted, frames are to be supported by horizontal primary support members spanning between the vertical primary support members.

5.4.3.4 The scantlings of web frames supporting longitudinal framing, stringers and transverse framing are to be determined from 3.11.3.

5.4.3.5 The web depth of primary support members is not to be less than 14 per cent of the bending span and is to be at least 2,5 times as deep as the slots for stiffeners if the slots are not closed.

5.5 Deck structure

5.5.1 Deck plating.

5.5.1.1 The thickness of the deck plating is to comply with the requirements in 3.11.2.1.

5.5.2 Deck stiffeners.

5.5.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

5.5.3 Deck primary support members.

5.5.3.1 The section modulus and shear area of primary support members are to comply with the requirements in 3.11.3.

5.5.3.2 The web depth of primary support members is not to be less than 10 per cent and 7 per cent of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2,5 times the depth of the slots if the slots are not closed. In the case of a grillage structure, the unsupported span is the distance between connections to other primary support members.

5.5.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

5.5.4 Pillars.

5.5.4.1 Pillars are to comply with the requirements of 3.5.4.

5.6 Tank bulkheads

5.6.1 General.

5.6.1.1 Tanks are to comply with the requirements of 3.6.

5.7 Watertight boundaries

5.7.1 General.

5.7.1.1 Watertight boundaries are to comply with the requirements of 3.7.

5.7.2 Aft peak bulkhead.

5.7.2.1 The scantlings of structural components of the aft peak bulkhead are to comply with the requirements in 3.6 and 3.7.2, as applicable.

5.8 Miscellaneous structures

5.8.1 Pillar bulkheads.

5.8.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports no less effective than those required for stanchions or pillars. The acting load and the required net cross-sectional area of the pillar section are to be determined using the requirements of 5.5.4. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$ of the plating, where t_{net} is net plating thickness, in mm.

5.8.1.2 Pillar bulkheads are to meet the following requirements:
(a) the distance between bulkhead stiffeners is not to exceed 1500 mm;
(b) where corrugated, the depth of the corrugation is not to be less than 100 mm.

5.8.2 **Rudder trunk.**

5.8.2.1 Where a rudder trunk is fitted, the scantlings are to be in accordance with the shell plating and framing in 5.4.1 and 5.4.2. Where the rudder trunk is open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment.

5.8.3 **Stern thruster tunnels.**

5.8.3.1 The net thickness of the tunnel plating, $t_{\text{tun-net}}$, is not to be less than required for shell plating in the vicinity of the thruster. In addition $t_{\text{tun-net}}$ is not to be taken less than:

$t_{\text{tun–net}}$ = $0{,}008 d_{\text{tun}} + 1{,}8$ m
where
d_{tun} = inside diameter of tunnel, in mm, but not to be taken less than 970 mm.

5.8.3.2 Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

■ *Section 6*
Evaluation of structure for sloshing and impact loads

6.1 Symbols

6.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres
L_2 = Rule length, L, but need not be taken greater than 300 m
B = moulded breadth, in metres
D = moulded depth, in metres
C_b = block coefficient
σ_{yd} = specified minimum yield stress of the material, in N/mm^2

$$\tau_{yd} = \frac{\sigma_{yd}}{\sqrt{3}} \text{ N/mm}^2$$

s = stiffener spacing, in mm
P = design pressure for the design load set being considered, in kN/m^2.

6.2 General

6.2.1 **Application.**

6.2.1.1 The requirements of this Section cover the additional strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid and local impact loads in the forward and aft structure. The impact loads to be applied in 6.4 are described in Ch 2,4.

6.3 Sloshing in tanks

6.3.1 **Scope and limitations.**

6.3.1.2 The requirements of the *ShipRight*–FOI procedure specify the methodology in assessing the scantling requirements for boundary and internal structure of tanks subject to sloshing loads, due to the free movement of liquid in tanks.

6.3.1.3 The structure of cargo tanks, slop tanks, ballast tanks and large deep tanks, e.g. fuel oil bunkering tanks and main fresh water tanks, are to be assessed for sloshing. Small tanks do not need to be assessed for sloshing pressures.

6.3.1.4 All cargo and ballast tanks are to have scantlings suitable for unrestricted filling heights.

6.3.1.5 The following structural members are to be assessed:
(a) plates and stiffeners forming boundaries of tanks;
(b) plates and stiffeners on wash bulkheads;
(c) web plates and web stiffeners of primary support members located in tanks;
(d) tripping brackets supporting primary support members in tanks.

6.4 Bottom slamming

6.4.1 Application.

6.4.1.1 Where the minimum draughts forward, $T_{FP\text{-}mt}$ or $T_{FP\text{-}full}$, as specified in Chapter 2, is less than 0,045*L*, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.

6.4.1.2 For self-propelling units with conventional single screw, ship-type aft sections, additional strengthening against aft slamming will not normally be required. For units with full deep aft sections, strengthening to resist bottom slamming should be applied over 0,3*L* aft, using the requirements of 6.4.3 and 6.4.4 and the applicable draughts aft. Units with raised or unusual sections aft that may be susceptible to slamming will be specially considered, using the requirements of Pt 4, Ch 2,4.3 and 5.2 of the Rules for Ships.

6.4.1.3 The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, *see* 1.2.

6.4.1.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The cross-sectional shear areas of primary support members are to be applied as required by 6.4.7.3 and 6.4.7.4.

6.4.1.5 For harsh service, special consideration should be given to strengthening of bottom forward in relation to the actual forces determined from model tests and/or direct calculations.

6.4.2 Extent of strengthening.

6.4.2.1 The strengthening is to extend forward of 0,3*L* from the F.P. over the flat of bottom and adjacent plating with attached stiffeners up to a height of 500 mm above the baseline, *see* Fig. 3.6.1.

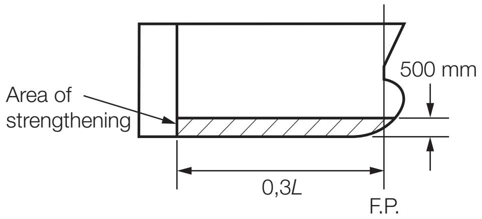


Fig. 3.6.1 Extent of strengthening against bottom slamming

6.4.2.2 Outside the region strengthened to resist bottom slamming, the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.4.3 Design to resist bottom slamming loads.

6.4.3.1 The design of end connections of stiffeners in the bottom slamming region is to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt\text{-}net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt\text{-}net} = \frac{16 Z_{pl\text{-}net}}{f_{bdg}} \text{ cm}^3$$

where

$Z_{pl\text{-}net}$ = net plastic section modulus, in cm^3, as required by 6.4.5.1

f_{bdg} = bending moment factor

$= 8\left(1 + \frac{n_s}{2}\right)$

n_s = 0 for both ends with low end fixity (simply supported)

= 1 for one end equivalent to built in and one end simply supported.

6.4.3.2 Scantlings and arrangements at primary support members, including bulkheads, are to comply with 6.4.7.

6.4.4 **Hull envelope plating**.

6.4.4.1 The net thickness of the hull envelope plating, t_{net}, is not to be less than:

$$t_{net} = \frac{0{,}0158\alpha_p s}{C_d}\sqrt{\frac{P_{slm}}{C_a \sigma_{yd}}} \text{ mm}$$

where

α_p = correction factor for the panel aspect ratio
= $1{,}2 - \dfrac{s}{2100 l_p}$ but not to be taken as greater than 1,0
l_p = length of plate panel, to be taken as the spacing between primary support members or panel breakers, in metres
P_{slm} = bottom slamming pressure as given in Ch 2,4.2.2.1 and calculated at the load calculation point, in kN/m^2
C_d = plate capacity correction coefficient
= 1,3
C_a = permissible bending stress coefficient
= 1,0 for acceptance criteria set AC3.

6.4.5 **Hull envelope stiffeners**.

6.4.5.1 The net plastic section modulus, Z_{pl-net}, of each individual stiffener, is not to be less than:

$$Z_{pl-net} = \frac{P_{slm}\, s\, l_{bdg}^2}{f_{bdg}\, C_s\, \sigma_{yd}} \text{ cm}^3$$

where

l_{bdg} = effective bending span, in metres
f_{bdg} = bending moment factor
= $8\left(1 + \dfrac{n_s}{2}\right)$
n_s = 2,0 for continuous stiffeners or where stiffeners are bracketed at both ends, *see* 6.4.3.1 for alternative arrangements
C_s = permissible bending stress coefficient
= 0,9 for acceptance criteria set AC3.

6.4.5.2 The net web thickness, t_{w-net}, of each longitudinal is not to be less than:

$$t_{w-net} = \frac{P_{slm}\, s\, l_{shr}}{2 d_{shr}\, C_t\, \tau_{yd}} \text{ mm}$$

where

l_{shr} = effective shear span, in metres
d_{shr} = effective web depth of stiffener, in mm
C_t = permissible shear stress coefficient
= 1,0 for acceptance criteria set AC3.

6.4.5.3 The slenderness ratio of each longitudinal is to comply with the *ShipRight*-FOI procedure.

6.4.6 **Definition of idealised bottom slamming load area for primary support members**.

6.4.6.1 The scantlings of items in 6.4.7 are based on the application of the slamming pressure defined in Chapter 2 to an idealised area of hull envelope plating, the slamming load area, A_{slm}, given by:

$$A_{slm} = \frac{1{,}1 L B C_b}{1000} \text{ m}^2$$

6.4.7 **Primary support members**.

6.4.7.1 The size and number of openings in web plating of the floors and girders are to be minimised, considering the required shear area as given in 6.4.7.2.

6.4.7.2 The net shear area, $A_{shr\text{-}net50}$, of each primary support member web at any position along its span is not to be less than:

$$A_{shr\text{-}net50} = 10 \frac{Q_{slm}}{C_t \tau_{yd}} \text{ cm}^2$$

where

Q_{slm} = the greatest shear force due to slamming for the position being considered, in kN, based on the application of a patch load, F_{slm}, to the most onerous location, as determined in accordance with 6.4.7.3

C_t = permissible shear stress coefficient

= 0,9 for acceptance criteria set AC3.

6.4.7.3 For simple arrangements of primary support members, where the grillage effect may be ignored, the shear force, Q_{slm}, is given by:

$$Q_{slm} = f_{pt} f_{dist} F_{slm} \text{ kN}$$

where

f_{pt} = correction factor for the proportion of patch load acting on a single primary support member

= $0{,}5\,(f_{slm}^3 - 2f_{slm}^2 + 2)$

f_{slm} = patch load modification factor

= $0{,}5 \dfrac{b_{slm}}{S}$, but not to be greater than 1,0

f_{dist} = factor for the greatest shear force distribution along the span, *see* Fig. 3.6.2

F_{slm} = $P_{slm}\, l_{slm}\, b_{slm}$

l_{slm} = extent of slamming load area along the span

= $\sqrt{A_{slm}}$ m, but not to be greater than l_{shr}

l_{shr} = effective shear span, in metres

b_{slm} = breadth of impact area supported by primary support member

= $\sqrt{A_{slm}}$ m, but not to be greater than S

A_{slm} = as defined in 6.4.6.1

S = primary support member spacing, in metres.

6.4.7.4 For complex arrangements of primary support members, the greatest shear force, Q_{slm}, at any location along the span of each primary support member is to be derived by direct calculation in accordance with Table 3.6.1.

Table 3.6.1 Direct calculation methods for derivation of Q_{slm}

Type of analysis	Beam theory	Double bottom grillage
Model extent	Overall span of member between effective bending supports	Longitudinal extent to be one cargo tank length Transverse extent to be between inner hopper knuckle and centreline
Assumed end fixity of floors	Fixed at ends	Floors and girders to be fixed at boundaries of the model

NOTE
The envelope of greatest shear force along each primary support member is to be derived by applying the load patch to a number of locations along the span, *see* 6.4.7.2.

6.4.7.5 The net web thickness, $t_{w\text{-}net}$, of primary support members adjacent to the shell is not to be less than:

$$t_{w\text{-}net} = \frac{s}{70} \sqrt{\frac{\sigma_{yd}}{235}} \text{ mm}$$

where

s_w = plate breadth, in mm, taken as the spacing between the web stiffening.

6.4.8 **Connection of longitudinals to primary support members**.

6.4.8.1 Longitudinals are, in general, to be continuous. Where this is not practicable, end brackets are to be provided.

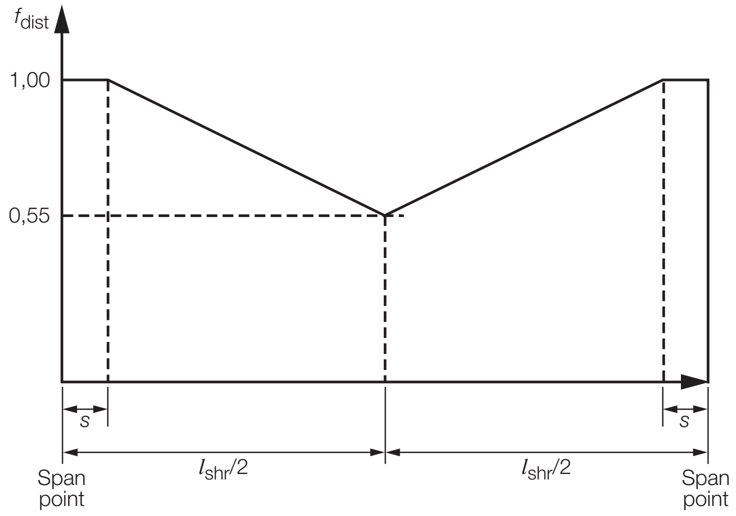
6.4.8.2 The scantlings in way of the end connections of each longitudinal are to comply with the requirements of 1.10.

6.5 Bow impact

6.5.1 **Application**.

6.5.1.1 The side structure in the area forward of 0,1*L* from the FP is to be strengthened against bow impact pressures.

6.5.1.2 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus of the primary support member is to apply along the bending span clear of end brackets and cross-sectional areas of the primary support member are to be applied at the ends/supports and may be gradually reduced along the span and clear of the ends/supports following the distribution of f_{dist} indicated in Fig. 3.6.2.



s = stiffener plating
l_{shr} = effective shear span, in metres

Fig. 3.6.2 Distribution of f_{dist} along the span of simple primary support members

6.5.2 **Extent of strengthening**.

6.5.2.1 The strengthening is to extend forward of 0,1*L* from the FP and vertically above the minimum design light load draught, T_{LT}, *see* Fig. 3.6.3.

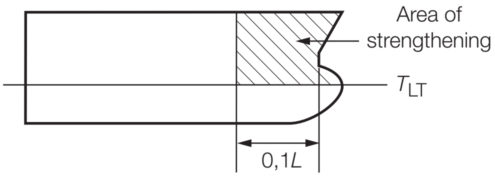


Fig. 3.6.3 Extent of strengthening against bow impact

6.5.2.2 Outside the strengthening region, as given in 6.5.2.1, the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.5.3 **Design to resist bow impact loads**.

6.5.3.1 In the bow impact region, longitudinal framing is to be carried as far forward as practicable.

6.5.3.2 The design of end connections of stiffeners in the bow impact region are to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{\text{pl-alt-net}}$, for alternative end fixity arrangements is not to be less than:

$$Z_{\text{pl-alt-net}} = \frac{16 Z_{\text{pl-net}}}{f_{\text{bdg}}} \text{ cm}^3$$

where

$Z_{\text{pl-net}}$ = effective net plastic section modulus, required by 6.5.5, in cm^3

f_{bdg} = bending moment factor

$= 8\left(1 + \frac{n_s}{2}\right)$

n_s = 0 for both ends with low end fixity (simply supported)

= 1,0 for one end equivalent to built in and one end simply supported.

6.5.3.3 Scantlings and arrangements at primary support members, including decks and bulkheads, are to comply with 6.5.7. In areas of greatest bow impact load, the adoption of web stiffeners arranged perpendicular to the hull envelope plating and the provision of double sided lug connections are, in general, to be applied.

6.5.3.4 The main stiffening direction of decks and bulkheads supporting shell framing is to be arranged parallel to the span direction of the supported shell frames, to protect against buckling.

6.5.4 **Side shell plating**.

6.5.4.1 The net thickness of the side shell plating, t_{net}, is not to be less than:

$$t_{\text{net}} = 0{,}0158 \alpha_p s \sqrt{\frac{P_{\text{im}}}{C_a \sigma_{\text{yd}}}} \text{ mm}$$

where

α_p = correction factor for the panel aspect ratio

$= 1{,}2 - \frac{s}{2100 l_p}$ but is not to be taken as greater than 1,0

l_p = length of plate panel, to be taken as the spacing between the primary support members, or panel breakers, in metres

P_{im} = bow impact pressure as given in Ch 2,4.3.2.1 and calculated at the load calculation point, in kN/m^2

C_a = permissible bending stress coefficient

= 1,0 for acceptance criteria set AC3.

6.5.5 **Side shell stiffeners**.

6.5.5.1 The effective net plastic section modulus, $Z_{\text{pl-net}}$, of each stiffener, in association with the effective plating to which it is attached, is not to be less than:

$$Z_{\text{pl-net}} = \frac{P_{\text{im}} s \, l_{\text{bdg}}^2}{f_{\text{bdg}} C_s \sigma_{\text{yd}}} \text{ cm}^3$$

where

l_{bdg} = effective bending span, in metres

f_{bdg} = bending moment factor

$= 8\left(1 + \frac{n_s}{2}\right)$

n_s = 2,0 for continuous stiffeners or where stiffeners are bracketed at both ends, *see* 6.4.3.1 for alternative arrangements

C_s = permissible bending stress coefficient

= 0,9 for acceptance criteria set AC3.

6.5.5.2 The net web thickness, $t_{\text{w-net}}$, of each stiffener is not to be less than:

$$t_{\text{w-net}} = \frac{P_{\text{im}}\, s\, l_{\text{shr}}}{2 d_{\text{shr}}\, C_{\text{t}}\, \tau_{\text{yd}}} \text{ mm}$$

where

l_{shr} = effective shear span, in metres
d_{shr} = effective web depth of stiffener, in mm
C_{t} = permissible shear stress coefficient
= 1,0 for acceptance criteria set AC3.

6.5.5.3 The slenderness ratio of each longitudinal is to comply with the *ShipRight*-FOI procedure.

6.5.5.4 The minimum net thickness of breasthooks/diaphragm plates, $t_{\text{w-net}}$, is not to be less than:

$$t_{\text{w-net}} = \frac{s}{70}\sqrt{\frac{\sigma_{\text{yd}}}{235}} \text{ mm}$$

where

s = spacing of stiffeners on the web, in mm. Where no stiffeners are fitted, s is to be taken as the depth of the web.

6.5.6 **Definition of idealised bow impact load area for primary support members**.

6.5.6.1 The scantlings of items in 6.5.7 are based on the application of the bow impact pressure to an idealised area of hull envelope plating, where the bow impact load area, A_{slm}, is given by:

$$A_{\text{slm}} = \frac{1{,}1 L B C_{\text{b}}}{1000} \text{ m}^2$$

6.5.7 **Primary support members**.

6.5.7.1 Primary support members in the bow impact region are to be configured to ensure effective continuity of strength and the avoidance of hard spots.

6.5.7.2 To limit the deflections under extreme bow impact loads and ensure boundary constraint for plate panels, the spacing, S, measured along the shell girth of web frames supporting longitudinal framing or stringers supporting transverse framing is not to be greater than:

$$S = 3 + 0{,}008 L_2 \text{ m}$$

6.5.7.3 End brackets of primary support members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.

6.5.7.4 Tripping brackets are to be fitted where the primary support member flange is knuckled or curved. The torsional buckling mode of primary support members is to be controlled by flange supports or tripping brackets. The unsupported length of the flange of the primary support member, i.e. the distance between tripping brackets, s_{bkt}, is not to be greater than:

$$s_{\text{bkt}} = b_{\text{f}}\, C \sqrt{\frac{235}{\sigma_{\text{yd}}} \frac{A_{\text{f-net50}}}{\left(A_{\text{f-net50}} + \dfrac{A_{\text{w-net50}}}{3}\right)}} \text{ m, but need not be less than } s_{\text{bkt-min}}$$

where

b_{f} = breadth of flange, in mm
C = slenderness coefficient:
= 0,022 for symmetrical flanges
= 0,033 for one-sided flanges
$A_{\text{f-net50}}$ = net cross-sectional area of flange, in cm^2
$A_{\text{w-net50}}$ = net cross-sectional area of the web plate, in cm^2
$s_{\text{bkt-min}}$ = 4,0 m.

6.5.7.5 The net section modulus of each primary support member, Z_{net50}, is not to be less than:

$$Z_{net50} = 1000 \frac{f_{bdg\text{-}pt} P_{im} b_{slm} f_{slm} l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \text{ cm}^3$$

where

$f_{bdg\text{-}pt}$ = correction factor for the bending moment at the ends and considering the patch load
= $3f_{slm}^3 - 8f_{slm}^2 + 6f_{slm}$
f_{slm} = patch load modification factor
= $\dfrac{l_{slm}}{l_{slm}}$
l_{slm} = extent of bow impact load area along the span
= $\sqrt{A_{slm}}$ m, but not to be taken as greater than l_{bdg}
A_{slm} = bow impact load area, in m^2, as defined in 6.4.6.1
l_{bdg} = effective bending span, in metres
b_{slm} = breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members, but not to be taken as greater than l_{slm}, in metres
f_{bdg} = bending moment factor
= 12 for primary support members with end fixed continuous face plates, stiffeners or where stiffeners are bracketed at both ends
C_s = permissible bending stress coefficient
= 0,8 for acceptance criteria set AC3.

6.5.7.6 The net shear area of the web, $A_{shr\text{-}net50}$, of each primary support member at the support/toe of end brackets is not to be less than:

$$A_{shr\text{-}net50} = \frac{5f_{pt} P_{im} b_{slm} l_{shr}}{C_t \tau_{yd}} \text{ cm}^2$$

where

f_{pt} = patch load modification factor
= $\dfrac{l_{slm}}{l_{shr}}$
l_{slm} = extent of bow impact load area along the span
= $\sqrt{A_{slm}}$ m, but not to be taken as greater than l_{shr}
l_{shr} = effective shear span, in metres
b_{slm} = breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members, but not greater than l_{slm}, in metres
C_t = permissible shear stress coefficient
= 0,75 for acceptance criteria set AC3.

6.5.7.7 The net web thickness of each primary support member, $t_{w\text{-}net}$, including decks/bulkheads in way of the side shell, is not to be less than:

$$t_{w\text{-}net} = \frac{P_{im} b_{slm}}{\sin \varphi_w \sigma_{crb}} \text{ mm}$$

where

b_{slm} = breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members, but not greater than l_{slm}, in metres
φ_w = angle, in degrees, between the primary support member web and the shell plate
σ_{crb} = critical buckling stress in compression of the web of the primary support member or deck/bulkhead panel in way of the applied load, in N/mm^2.

6.5.8 **Connection of stiffeners to primary support members**.

6.5.8.1 Stiffeners are, in general, to be continuous. Where this is not practicable, end brackets are to be provided.

6.5.8.2 The scantlings of the end connection of each stiffener are to comply with the requirements of 1.10.

Section 7
Application of scantling requirements to other structure

7.1 Symbols

7.1.1 The symbols used in this Chapter are defined as follows:

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

τ_{yd} = $\dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

s = stiffener spacing, in mm

S = primary support member spacing, in metres

F = point load for the design load set being considered, in kN

P = design pressure for the design load set being considered, in kN/m^2.

7.2 General

7.2.1 **Application**.

7.2.1.1 The requirements of this Section apply to plating, local and primary support members where the basic structural configurations or strength models assumed in Sections 2 to 5 are not appropriate. These are general purpose strength requirements to cover various load assumptions and end support conditions.

7.2.1.2 The requirements for local and primary support members are to be specially considered when the member is:
(a) part of a grillage structure;
(b) subject to large relative deflection between end supports;
(c) where the load model or end support condition is not given in Table 3.7.2.

7.2.1.3 The application of alternative or more advanced calculation methods will be specially considered.

7.3 Scantling requirements

7.3.1 **General**.

7.3.1.1 The design load sets to be applied to the structural requirements for the local and primary support members are given in Table 3.2.7, as applicable for the particular structure under consideration. The static and dynamic load components are to be combined in accordance with Table 2.6.1 and the requirements given in Chapter 2.

7.3.2 **Plating and local support members**.

7.3.2.1 For plating subjected to lateral pressure, the net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets, and given by:

$$t_{net} = 0{,}0158\alpha_p\, s\sqrt{\frac{|P|}{C_a\,\sigma_{yd}}}\ \text{mm}$$

where

α_p = correction factor for the panel aspect ratio

= $1{,}2 - \dfrac{s}{2100 l_p}$

l_p = length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in metres

C_a = permissible bending stress coefficient for the design load set being considered, as given in Tables 3.2.4, 3.3.2 or 3.4.2, as applicable for the individual member being considered.

7.3.2.2 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net section modulus requirement, Z_{net}, is to be taken as the greatest value for all applicable design load sets, and given by:

$$Z_{net} = \frac{|P|\, s\, l_{bdg}^2}{f_{bdg}\, C_s\, \sigma_{yd}}\ \text{cm}^3\text{, for lateral pressure loads}$$

$$Z_{net} = \frac{1000\,|F|\,l_{bdg}}{f_{bdg}\,C_s\,\sigma_{yd}}\ \text{cm}^3\text{, for point loads}$$

$$Z_{net} = \frac{\left|\sum \dfrac{P_i\,s\,l_{bdg}^{\,2}}{f_{bdg\text{-}i}} + \sum \dfrac{1000F_j\,l_{bdg}}{f_{bdg\text{-}j}}\right|}{C_s\,\sigma_{yd}}\ \text{cm}^3\text{, for a combination of loads}$$

where

l_{bdg} = effective bending span, in metres
f_{bdg} = bending moment factor
for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having fixed ends:
= 12 for horizontal stiffeners
= 10 for vertical stiffeners
for other configurations the bending moment factor may be taken as in Table 3.7.2
C_s = permissible bending stress coefficient for the design load set being considered as given in Tables 3.2.5, 3.3.3 or 3.4.3, as applicable for the individual member being considered
i = indices for load component i
j = indices for load component j.

7.3.2.3 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net web thickness, $t_{w\text{-}net}$, based on shear area requirements is to be taken as the greatest value for all applicable design load sets, and given by:

$$t_{w\text{-}net} = \frac{f_{shr}\,|P|\,s\,l_{shr}}{d_{shr}\,C_t\,\tau_{yd}}\ \text{mm, for lateral pressure loads}$$

$$t_{w\text{-}net} = \frac{1000f_{shr}\,|F|}{d_{shr}\,C_t\,\tau_{yd}}\ \text{mm, for point loads}$$

$$t_{w\text{-}net} = \frac{\left|\sum f_{shr\text{-}i}\,P_i\,s\,l_{shr} + \sum 1000f_{shr\text{-}j}\,F_j\right|}{d_{shr}\,C_t\,\tau_{yd}}\ \text{mm, for a combination of loads}$$

where

f_{shr} = shear force factor
for continuous stiffeners with end connections consistent with the idealisation of the stiffener as having fixed ends:
= 0,5 for horizontal stiffeners
= 0,7 for vertical stiffeners
for other configurations the shear force factor may be taken as in Table 3.7.2
l_{shr} = effective shear span, in metres
d_{shr} = effective shear depth, in mm
C_t = permissible shear stress coefficient for design load set, as given in Tables 3.2.6 or 3.3.4, for the individual member being considered
i = indices for load component i
j = indices for load component j.

7.3.3 **Primary support members**.

7.3.3.1 The requirements in 7.3.3 are applicable where the primary support member is idealised as a simple beam. More advanced calculation methods may be required to ensure that nominal stress levels for all primary support members are less than the permissible stresses and stress coefficients given in 7.3.3.4 and 7.3.3.5, when subjected to the applicable design load sets. *See also* 7.1.1.4.

7.3.3.2 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross-sectional shear areas of the primary support member are to be applied as required in the notes of Table 3.7.2.

7.3.3.3 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include an allowance for the curvature of the hull.

7.3.3.4 For primary support members, the net section modulus requirement, Z_{net50}, is to be taken as the greatest value for all applicable design load sets, and given by:

$$Z_{net50} = \frac{1000\,|P|\,S\,l_{bdg}^{2}}{f_{bdg}\,C_{s\text{-}pr}\,\sigma_{yd}} \text{ cm}^3\text{, for lateral pressure loads}$$

$$Z_{net50} = \frac{1000\,|F|\,l_{bdg}}{f_{bdg}\,C_{s\text{-}pr}\,\sigma_{yd}} \text{ cm}^3\text{, for point loads}$$

$$Z_{net50} = \frac{\left|\sum \dfrac{1000 P_i\,S\,l_{bdg}^{2}}{f_{bdg\text{-}i}} + \sum \dfrac{1000 F_j\,l_{bdg}}{f_{bdg\text{-}j}}\right|}{C_{s\text{-}pr}\,\sigma_{yd}} \text{ cm}^3\text{, for a combination of loads}$$

where

l_{bdg} = effective bending span, in metres
f_{bdg} = bending moment factor, as given in Table 3.7.2
$C_{s\text{-}pr}$ = permissible bending stress coefficient as given in Table 3.7.1 for design load set given in Table 3.2.7, for the individual member being considered
$_i$ = indices for load component i
$_j$ = indices for load component j.

7.3.3.5 For primary support members, the net shear area of the web, $A_{shr\text{-}net50}$, is to be taken as the greatest value for all applicable design load sets, and given by:

$$A_{shr\text{-}net50} = \frac{10 f_{shr}\,|P|\,S\,l_{shr}}{C_{t\text{-}pr}\,\tau_{yd}} \text{ cm}^2\text{, for lateral pressure loads}$$

$$A_{shr\text{-}net50} = \frac{10 f_{shr}\,|F|}{C_{t\text{-}pr}\,\tau_{yd}} \text{ cm}^2\text{, for point loads}$$

$$A_{shr\text{-}net50} = \frac{\left|\sum 10 f_{shr\text{-}i}\,P_i\,s\,l_{shr} + \sum 10 f_{shr\text{-}j}\,F_j\right|}{C_{t\text{-}pr}\,\tau_{yd}} \text{ cm}^2\text{, for a combination of loads}$$

where

l_{shr} = effective shear span, in metres
f_{shr} = shear force factor, as given in Table 3.7.2
$C_{t\text{-}pr}$ = permissible shear stress coefficient as given in Table 3.7.1 for design load set given in Table 3.2.7, for the individual member being considered
$_i$ = indices for load component i
$_j$ = indices for load component j.

Table 3.7.1 Permissible stress coefficients, $C_{s\text{-}pr}$ and $C_{t\text{-}pr}$, for primary support members

Acceptance criteria set	Permissible bending stress coefficient, $C_{s\text{-}pr}$	Permissible shear stress coefficient, $C_{t\text{-}pr}$
AC1	0,70	0,70
AC2	0,85	0,85

Table 3.7.2 Values of f_{bdg} and f_{shr} (*continued*)

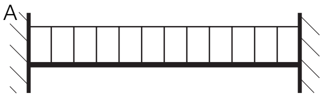
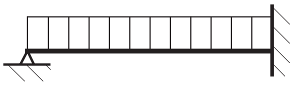
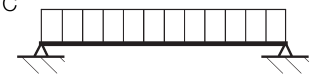
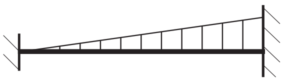
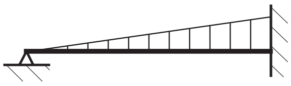
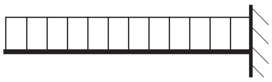
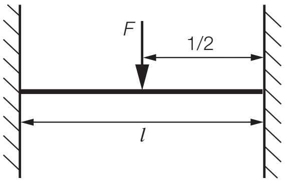
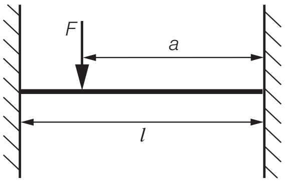
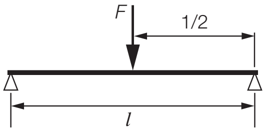
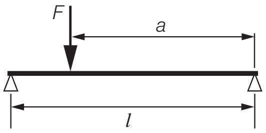
Load and boundary conditions				Bending moment and shear force factor (based on load at mid span where load varies)			Application
Load model		Position (1)		1	2	3	
	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} —	f_{bdg3} f_{shr3}	
	A 			12,0 0,50	24,0 —	12,0 0,50	Built in at both ends Uniform pressure distribution
	B 			— 0,38	14,2 —	8,0 0,63	Built in at one end plus simply supported one end Uniform pressure distribution
	C 			— 0,50	8,0 —	— 0,50	Simply supported, (both ends are free to rotate) Uniform pressure distribution
	D 			15,0 0,30	23,3 —	10,0 0,70	Built in at both ends Linearly varying pressure distribution
	E 			— 0,20	16,8 —	7,5 0,80	Built in at one end plus simply supported one end Linearly varying pressure distribution
	F 			— —	— —	2,0 1,0	Cantilevered beam Uniform pressure distribution
	G 			8,0 0,5	8,0 —	8,0 0,5	Built in at both ends Single point load in the centre of the span
	H 			$\frac{l^3}{a^2(l-a)}$ $\frac{a^2(3l-2a)}{l^3}$	$\frac{l^4}{2a^2(l-a)^2}$ —	$\frac{l^3}{a(l-a)^2}$ $\frac{(l-a)^2(l+2a)}{l^3}$	Built in at both ends Single point load, with load anywhere in the span
	I 			— 0,5	4 —	— 0,5	Simply supported Single point load in the centre of the span
	J 			—	$\frac{l^2}{a(l-a)}$	—	Simply supported Single point load, load anywhere along the span

Table 3.7.2 Values of f_{bdg} and f_{shr} (*conclusion*)

Symbols

l = effective span, l_{bdg} and l_{shr}, as applicable
l_{bdg} = effective span in bending, for local or primary support members, in metres
l_{shr} = effective span in shear, for local or primary support members, in metres

NOTES

1. The bending moment factor, f_{bdg}, for the support positions is applicable for a distance of $0{,}2l_{bdg}$ from the end of the effective bending span for both local and primary support members.
2. The shear force factor, f_{shr}, for the support positions is applicable for a distance of $0{,}2l_{shr}$ from the end of the effective shear span for both local and primary support members.
3. Application of f_{bdg} and f_{shr} for local support members:
   (a) the section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1}, f_{bdg2} and f_{bdg3}
   (b) the shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3}.
4. Application of f_{bdg} and f_{shr} for primary support members:
   (a) the section modulus requirement within $0{,}2l_{bdg}$ from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3}; however f_{bdg} is not to be taken greater than 12
   (b) the section modulus of mid span area is to be determined using $f_{bdg} = 24$, or f_{bdg2} from the Table if lesser
   (c) the shear area requirement of end connections within $0{,}2l_{shr}$ from the end of the effective span is to be determined using $f_{shr} = 0{,}5$ or the applicable f_{shr1} or f_{shr3}, whichever is greater
   (d) for models A through F, the value of f_{shr} may be gradually reduced outside of $0{,}2l_{shr}$ towards $0{,}5f_{shr}$ at mid span, where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

Section

1 **General**

■ *Section 1*
General

1.1 Application

1.1.1 The requirements for Ship units are given in Part 10 of these Rules.

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